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INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kĭl'o
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mi'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	ăt'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb.
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g

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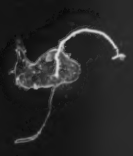

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RADIOLOGICAL HEALTH DATA AND REPORTS

Volume 11, Number 1, January 1970

In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the Bureau of Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the Bureau of Radiological Health by Federal agencies, State health departments, universities, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators.

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Reports

Diagnostic Dental X Rays and the Patient–an Overview

Bureau of Radiological Health

In 1964, approximately one quarter of the civilian non-institutional population in the United States was exposed to dental x rays. The average estimated skin exposure was 1,144 mR per film. The absorbed doses were on the order of 25–80 mrad to organs in or near the direct beam with a genetically significant dose of <0.01 mrad per year. The status of exposure control programs and standards and compliance is discussed and activities for further reducing exposure are identified.

In order to evaluate the overall significance of the various sources of ionizing and non-ionizing radiation which may result in exposure to the U.S. population, it is necessary to place the contributions of each source into perspective. The purpose of this paper is to review the dental x-ray experience of the U.S. population, present exposure and dose estimates for this source of radiation and to summarize the current status of standards and compliance in the United States. Recommendations are made to further define unknown parameters and to reduce patient exposure from this source of x-radiation.

The annual exposure received by a population from diagnostic dental x rays is dependent not only on the parameters that affect the amount of radiation emitted from dental x-ray machines, but also on the frequency of dental x-ray examinations in a given population. Recent surveys have provided information on the number of people in various population groups who had diagnostic medical (*1–3*) and dental x-ray examinations (*4*). Such information is now available for the United States civilian population from a study (*5*) conducted by the U.S. Public Health Service in 1964. Estimates from the latter study indicate that 108 million (58 percent) of the 187 million civilian non-institutional persons in the population had one or more x-ray visits during 1964; about 46 million of these had dental x rays. Moreover, 12 percent of this group had more than one dental examination during that year.

Variations were found in the dental x-ray visits for different demographic groups of the population (*5*). The rate of dental x-ray visits is higher among females than among males in each age group; the highest rate among males was in the age group 30–44 years, while for females the rate was highest in the 15–29 year age group (table 1). Data in table 2 indicate that dental x-ray visits are positively correlated with family income and education level of the head of the household; the annual rate of dental visits among white persons is about three times the rate among the non-white populations; people who reside in rural areas have lower rates of visits for dental x-ray examinations than do

Table 1. Estimated annual rate of dental x-ray visits in the United States by age and sex, 1964[a]

Age	Dental x-ray visits per 100 persons		
	Both sexes	Male	Female
Under 15	20.6	18.5	22.8
15–29	37.6	30.4	44.1
30–44	36.0	33.6	38.2
45 and over	20.2	18.7	21.6
All ages	26.8	23.7	29.8

[a] PHS X-ray Exposure Study (*5*) page 78.

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Table 2. Estimated annual rate of dental x-ray visits by selected population characteristics, United States, 1964[a]

Selected population characteristics	Dental x-ray visits per 100 persons
Education of household head:	
0–8th grade	10.2
9–12th grade	28.7
College	48.5
Family income:	
Under $2,000	11.3
$2,000–$3,999	15.0
$4,000–$6,999	23.2
$7,000 and over	39.9
Color:	
White	29.2
Non-white	8.8
Residence:	
Metropolitan	30.8
Non-metropolitan	
Non-farm	20.9
Farm	12.4
Region:	
Northeast	32.2
North Central	24.7
South	17.2
West	39.5

[a] PHS X-ray Exposure Study (*5*) page 79.

people who live in metropolitan areas; the West had the highest rate of visits and the South, the lowest.

Another indicator of the extent of radiation exposure to the population from diagnostic dental x-ray procedures is the number of radiographic units used for dental purposes. Preliminary data on State and local radiological health programs (*6*) for fiscal year 1967 indicate that there were about 213,800 x-ray machines in the United States of which 100,500 were dental units.

Exposure estimates

From unpublished data of the 1964 survey, average exposures at the skin surface per dental film have been estimated for selected age groups, projections, film speeds and kVp settings (table 3). In 1964, about 53.6 million dental x-ray examinations were performed using 226.7 million films. Periapical[1] and bitewing[2] projections accounted for 99 percent of the film exposures. The average incident skin exposure per film for these techniques is estimated to be 1,144 mR per film (table 3). For individuals 15 years of age and over, the average exposure per film is 1.4 times as high as for children under 15 years; the older group was exposed to almost twice as many films per 100 persons as the younger group. The exposure per film using the periapical technique, which is used twice as frequently as the bitewing, is about 10 percent lower than that for the latter technique.

Table 3. Estimated average exposure to patient per dental film by age, type of projection, film speed and kVp technique, United States, 1964[a]

Category	Estimated average exposure per film[b] (mR at skin entrance)	Percent of films exposed	Annual rate of films exposed per 100 persons in the population
Age of patient:			
Under 15 years	873		78.7
15 years and over	1,220		139.2
All ages	1,144		120.1
Projection:			
Periapical	1,103	67.1	
Bitewing	1,223	32.9	
All projections	1,144	100.0	
Film speed:[c]			
Slow (A)[d]	1,759	5.7	
Intermediate (B&C)	1,633	37.6	
Fast (D)	606	41.7	
Unknown	1,265	15.0	
All film speeds	1,144	100.0	
kVp technique[e]			
45–50	(f)	3.8	
51–65	1,340	58.6	
66–80	1,020	21.1	
81–90	775	16.5	
All kVp	1,144	100.0	

[a] All data in this table are limited to results obtained for the periapical and bitewing projections and is made up from unpublished data from the 1964 x-ray survey by the Division of Radiological Health.
[b] Exposures based on total number of films for which all factors required to calculate exposure at skin entrance were known.
[c] The letters in parentheses for each film speed category represent the classifications as designated in "American Standard Speed Classification for Intraoral Dental Radiographic Film: Diagnostic Grade, ASA Standard (now American National Standards Institute) PH 6.1–1961."
[d] No longer marketed.
[e] Most of the film included in the 51–65 kVp group were exposed using a 65 kVp technique; in the 66–80 group, using a 70 kVp technique; and in the 81–90 group, using a 90 kVp technique.
[f] Sufficient data to prepare valid estimates were not available.

Among dentists who used fast-speed film (D),[3] the average exposure was approximately one-third that for dentists who used slow or intermediate speed films (A, B, C).[3] Approximately 42 percent of the films used in 1964 were classified as fast-speed. The average exposure at the skin surface per film among dentists using the 90 kVp technique[4] was about three-fifths that for the 65 kVp technique.[5] Approximately 59 percent of the films exposed in 1964 were taken with the latter technique.

[1] The periapical projection is used primarily to study the root of the tooth and the surrounding structures.
[2] The bitewing projection is used primarily to detect caries between the posterior teeth.

[3] See footnote "c" of table 3.
[4] Includes exposures made using the 81–90 kVp technique.
[5] Includes exposures made using the 51–65 kVp technique.

An additional observation from the 1964 study was the correlation between the average exposure per film and the dentist's year of graduation from dental school. The average exposure to patients in offices of dentists graduated after 1940 was observed to be almost two-thirds of the average exposure received by patients in offices of dentists graduated prior to that date. This fact may reflect the use of newer x-ray equipment, faster films, better darkroom techniques and special training in good radiation hygiene practice (*5*).

Dose estimates

From available literature, it appears that only a limited amount of experimental work has been done to determine doses from diagnostic dental x-rays. A few studies, however, have measured or estimated doses from dental x rays to various organs or tissues of the body. While some of these doses were originally presented in terms of roentgens, in this report it is assumed that 1 roentgen corresponds to 1 rad or 1 rem in soft tissue (*7*). Table 4 presents absorbed dose estimates from dental radiography compared with certain doses from natural background. The doses for the eye and thyroid are from Richards and Webber (*11*) who used a phantom in which miniature dosimeters were imbedded and determined the dose to various parts of the body from a dental x-ray unit operating at what were considered to be conventional machine settings before 1965.

It should be noted that the highest gonadal dose for females would be even lower than that for males since it has been estimated this dose is about one-fifth that for males (*12*).

Table 4. Comparison of absorbed dose estimates from dental radiography with dose estimates from natural background

Organ	Dose	
	Dental x rays	Natural background
Eye (*8*)	28[a] to 27[b] mrads per bitewing[c] examination (2 films) 77[d] to 79[e] mrads per periapical[f] examination (14 films)	
Thyroid (*8*)	39[a] to 44[b] mrads per bitewing[c] examination (2 films) 49[d] to 48[e] mrads per periapical[f] examination (14 films)	
Bone marrow	3 rad mean active mandible bone marrow dose per film (*8*)[g]	
Male gonads	<0.01 to 0.02 mrads per film (*9*)	100 mrad per year (*10*)
Genetically significant dose[h]	<0.01 mrad per year (*9*)	

[a] x-ray machine setting 65 kVp, 10 mA, 3.0 sec for two films.
[b] x-ray machine setting 90 kVp, 10 mA, 1.2 for two films.
[c] Medium-speed film utilized.
[d] x-ray machine setting 65 kVp, 10 mA, 3.4 sec for 14 films.
[e] x-ray machine setting 90 kVp, 10 mA, 1.36 sec for 14 films.
[f] High-speed film utilized.
[g] Based upon an integrated dose of 3g-rad to 25 percent of the active bone marrow of the mandible assuming 1 R skin exposure is equivalent to 1 rad bone marrow dose.
[h] The genetically significant dose (GSD) is an index of radiation received by the genetic pool which determines the progeny of a given population.

Exposure control

Review of those aspects of dental x-ray exposure for which standards can be developed, along with review of the existing guidance for control or reduction of dental x-ray exposure, suggest the dental x-ray control categories outlined in table 5. The status of standards and compliance in each of these categories is discussed in the table.

In 1962, only 7 States[6] had specific regulations, while some 38 additional States employed recommended standards (*13*). By July 1967, however, all States had some kind of compliance program relating to dental x-ray equipment and/or techniques to reduce radiation during dental x-ray examinations. Twenty-six of the State programs may be classified as regulatory, 17 States have voluntary programs and 10 States have a combination of regulatory and voluntary programs (*6*). Although all States include guides for filtration and collimation, the minimum requirements for these and other guides, standards and regulations vary from State to State.

Approximately 91 percent of the estimated 100,500 dental x-ray units in the United States had been registered by July 1967 by the 47 States[6] with registration programs (*6*). This is a significant increase from the 22,550 units that had been registered by July 1962 in 18 States (*13*).

Before 1960, less than 25 percent of the x-ray machines surveyed met the minimum requirements for filtration and collimation (*13*). By the end of fiscal 1967, approximately 89 percent of the estimated 100,500 dental units had been inspected, at least once, by the States and at least 73 percent of all units were in full compliance with the respective State regulations. During fiscal year 1967, 5,322 dental machines were brought into compliance.

[6] State figures include the District of Columbia, Puerto Rico and the Virgin Islands.

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Table 5. Status of dental x-ray exposure control categories

Control categories	Status
Basic radiation protection guidance	All groups concerned with providing guidance for minimizing radiation from man-made sources (*14–19*) have pointed out that exposure from x rays may have deleterious genetic and/or somatic effects. They stress that all unnecessary exposure from incremental radiation should be avoided and recommend that the benefits versus the possible risks to the patient should always be considered. The basic exposure guidance has stressed keeping exposure to x rays as low as possible through control of all physical variables and advised the practitioner to use the minimum radiation, in his judgment, consistent with the benefit to the patient. (*20–23*).
Equipment, design and operation	Primary emphasis has been directed towards studying each aspect of the x-ray machine in order to make recommendations for minimizing the exposure to the patient. Also, as has been pointed out, there has been a progressive effort by the State governments since 1960 to survey the physical characteristics of the machines and to followup these surveys to insure that the corrections were made and to resurvey for continued checks on compliance.
Film utilization	The use of fast film and strict adherence to complete development techniques for developing and processing is one of the areas which will keep the radiation applied to the patient to the minimum consistent with adequate dental practices (*23*). However, information is not readily available on the use of fast-speed films and information is not available on a nationwide basis about film developing and processing techniques used in dental offices.
Patient protection (diagnostic procedures)	Implementation of procedures such as use of leaded rubber aprons, limited field sizes and adequate filtration will lower the extraneous dose to other parts of the body while the area under study receives the minimum radiation necessary to produce a good quality radiographic image (*18*). No data are available on a nationwide basis indicating the number of dentists who use recommended procedures other than filtration and collimation. Exposures of children and pregnant women should be restricted to an absolute minimum (*22*).
Training of dentists or dental auxiliary personnel	No current summary of data for the country is available regarding the number of dental auxiliary personnel or dentists who have received special instruction in x-ray protection procedures, however, one State, Oregon, requires dental auxiliary personnel to pass an examination on radiation hygiene practice (*24*). All dentists should continue their education in radiology as well as other areas of dental practice (*18*).

Sufficient recommendations for each dental x-ray control category exist which, if accepted, would lead to a substantial reduction in exposure and yet not interfere with the exercise of clinical judgment of the practitioner. The regular inspection of dental x-ray units and follow-up surveys of units that did not meet the minimum standards for filtration and collimation have resulted in a major reduction of patient x-ray exposure. An even greater reduction of x-ray exposure would be expected if minimal State standards were devised to include optimum darkroom and film techniques and possibly special training of dental auxiliary personnel in good radiation hygiene practices and film processing.

Recommendations

The following activities have potential for further reducing exposure to the patient from diagnostic dental x-rays or in providing further definition of exposure from this radiation source:

1. Development of a uniform standard with criteria which specify the use of dental x-ray equipment and operational procedures that produce a minimum amount of patient radiation for a given examination;
2. extension of minimum standards of all States to include required special instruction of dentists and auxiliary personnel;

3. continued surveys, documentation and corrective follow-up of the physical characteristics of x-ray equipment by State and Federal agencies to minimize radiation exposure from dental radiography;
4. further clarification of dose estimates either by physical measurements or suitable mathematical models; and
5. a survey of trends in dental public health that may affect the frequency and number of x-ray examinations required to maintain good dental health.

Acknowledgements

Radiation exposure overviews are prepared through a cooperative effort by the Divisions and Offices of the Bureau of Radiological Health which are concerned with various aspects of the definition and control of the radiation exposure source under study, and coordinated by the Office of Criteria and Standards. The following individuals prepared the report: Anne G. Berger (deceased), Warren A. Brill, William H. Oates, Jr., and Marvin Rosenstein, Office of Criteria and Standards, with technical assistance from Ray W. Alcox, D.D.S., Division of Medical Radiation Exposure, and James J. Laubham, Jr., D.D.S., Division of Biological Effects.

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Evaluation of Emissions from Radium Dial Watches

Herbert F. Klein, Earl W. Robinson, Royce L. Gragg, and James W. Rolofson[1]

Seventeen U.S. Army surplus radium-dial pocket watches were examined for radium content. The absorbed dose rates at the surface of the watches were measured and found to vary from 23.8 to 36.1 mrad/h-μCi. A simulated radium dial watch was constructed and used to estimate absorbed dose rates to various parts of the human body.

During 1968, 3,154 radium-activated, self-luminous pocket watches were released by the U.S. Army through government surplus channels to certain State surplus property agencies. In March 1968, the Bureau of Radiological Health (BRH) (then the National Center for Radiological Health) notified the radiological health agencies of these States that this distribution had been made and recommended that "these watches either not be distributed or be distributed with restrictions." This action was based on preliminary measurements of the radium content of the watches, the IAEA recommendation that radium not be used in pocket watches (*1*), and the public health objective of reducing unnecessary exposure. Subsequently, 1,700 of the watches were removed from State and Federal surplus channels and shipped to the Bureau of Radiological Health for disposal as radioactive waste (*2*).

A study was conducted by the Division of Medical Radiation Exposure, BRH, to evaluate the potential external radiation exposure from the use of these radium-activated self-luminous pocket watches. Measurements were made of (1) the radium content of a sample from the surplus watches, (2) surface absorbed dose rate from a part of the sample group, and (3) absorbed dose to various anatomical sites within a human phantom using a high radium content, simulated pocket watch.

Radium content of watches

The radium content of a sample of 17 watches was measured (table 1). A NaI detector and multichannel analyzer were used to compare the radio-

Table 1. Radium content of watches

Watch number	Measured content (μCi)
1	1.39
2	1.36
3	1.35
4	1.30
5	1.16
6	1.09
7	1.07
8	1.07
9	1.04
10	1.02
11	.95
12	.91
13	.85
14	.82
15	.78
16	.68
17	.60
Average	1.03

[1] Messrs Klein, and Gragg are on the staff of the Division of Electronic Products; Mr. Robinson is on the staff of the Division of Medical Radiation Exposure; and Mr. Rolofson is on the staff of the Division of Biological Effects; Bureau of Radiological Health, Environmental Control Administration, Consumer Protection and Environmental Health Service, Department of Health, Education, and Welfare.

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activity of the watches with a standard constructed by removing the hands and dial plate from a sample watch and taping a calibrated 9.73 μCi radium-cell-loaded tube behind the center of the crystal. The intact watches were covered with 1 mm of lead, which closely approximates the 0.5 mm platinum-iridium filtration of the calibrated radium cell. All watches were counted at 9.75 inches from the center of the NaI crystal; counts were integrated under the 0.61 MeV peak of bismuth–214 after subtracting the background.

Surface absorbed dose measurements

In order to measure the absorbed dose rate at the surface of the watches, a paraffin phantom (figure 1) was constructed with recesses for the watch and for 5 lithium fluoride dosimeters.

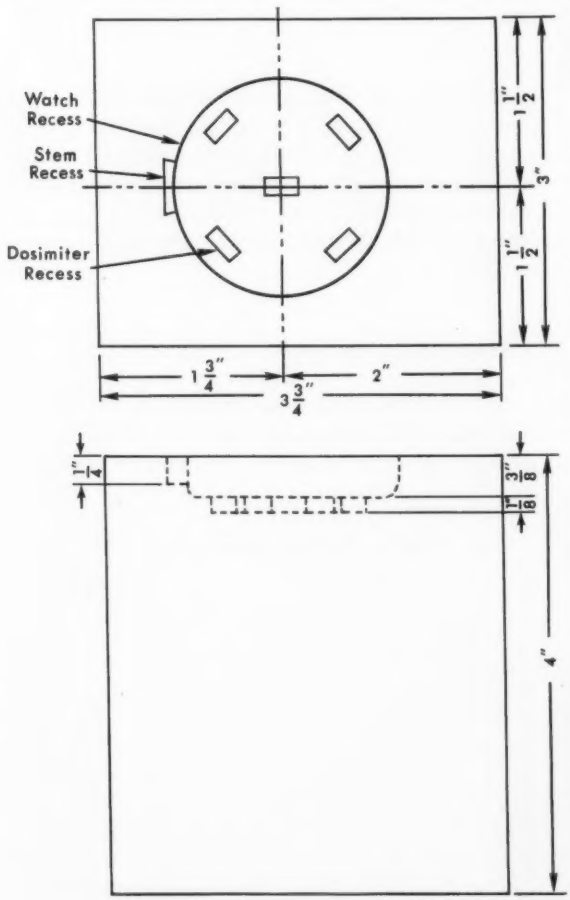

Figure 1. Paraffin phantom

The phantom was constructed of a tissue-equivalent mix (*3*) and was designed to approximate the backscatter of the human body. Each dosimeter consisted of a preannealed hot-pressed TLD-100 lithium fluoride rod in a number 5 gelatin capsule.

Eight of the watches listed in table 1 were selected for these measurements. The watch under test was placed, crystal down, in the 3/8-inch deep recess in the phantom. The phantom was next inverted to place the dosimeters closer to the watch face and to produce a more uniform dosimeter-crystal orientation in each dosimeter location. Dosimeters were exposed to the emissions from the watch for approximately 25 hours during which time the watch was running. Doses were then measured using a dose-response relationship determined after each annealing. Additional measurements were made after placing 1 millimeter of lead between the watch and the dosimeters. The average dose rate was calculated from the doses to the 5 dosimeters (table 2). For each watch, the maximum dose measured by a single TLD was within a range of 2.1–3.6 times the minimum except for one watch whose range was greater.

Table 2. Average surface absorbed dose rate

Watch number	Radium content (μCi)	Dose rate at crystal		
		Filtered (1 mm Pb) (mrad/h)	Unfiltered (mrad/h)	Unfiltered (mrad/h-μCi)
2	1.36	3.48	49.1	36.1
3	1.35	3.24	42.9	31.8
4	1.30	3.18	35.1	27.0
6	1.09	2.60	30.0	27.5
7	1.07	2.78	29.3	27.4
11	.95	2.42	22.8	24.0
12	.91	2.37	27.8	30.5
13	.85	2.35	20.2	23.8
Average				28.5

The unfiltered measurements include exposure to beta particles. The lithium fluoride response per rad of beta radiation is equal to that from gamma radiation in the beta and gamma energy range of radium and its daughters. Therefore, the difference between the unfiltered and the filtered absorbed dose rate can be considered as the beta and soft gamma absorbed dose rate, since 99.9 percent of the beta particles less than 2 MeV are absorbed by the 1 mm lead filter used, and more than 40 percent of the gamma photons of less than 0.3 MeV are absorbed.

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Table 3. Absorbed dose distribution within phantom

Body organ	Absorbed dose rate from simulated watch (mrad/h)	Calculated absorbed dose rate per μCi (μrad/h)	Annual absorbed dose per μCi for a 16 hour day (mrad)
Testes (average R + L)	42.5	10.3	60.0
Uterus (P)[a]	74.5	18.0	105.0
Ovary (R)[a]	132.3	32.0	187.0
(L)	66.2	16.0	93.5
Bladder (A)	67.8	16.4	96.0
Spine L–3 (P)	132.0	32.0	187.0
Gall bladder (A)	240.0	58.2	340.0
Kidney (L)	36.0	8.7	51.0
Colon, transverse (A)	113.0	27.4	160.0
Spine T–11 (P)	16.0	3.9	22.7
Liver (P)	20.0	4.9	28.3
Spine T–6 (P)	6.0	1.5	8.5
Lung, superior lobe (R—P)	7.2	1.7	10.2
(L—P)	4.9	1.2	6.9
Lung, superior lobe (R—A)	10.4	2.5	14.7
(L—A)	5.1	1.2	7.2
Body of sternum (A)	8.1	2.0	11.4
Spine C–7 (P)	3.0	0.7	4.3
Thyroid gland (A)	3.3	0.8	4.7
Sternum (superficial)	6.1	1.5	8.6
Thyroid (inferior to laryngeal prominence)	3.0	0.7	4.3
Spine C–5 (P)	2.9	0.7	4.1
Thyroid (parathyroid L)	2.6	0.6	3.7
(parathyroid R)	2.6	0.6	3.7

[a] These data are included only for anatomical reference of "dose" distribution, since the assumption is made that women do not carry pocket watches.
(P)-Posterior
(A)-Anterior
(L)-Left side
(R)-Right side

The unfiltered surface absorbed dose rate per microcurie of radium is also shown in table 2. This dose rate varies from 23.8–36.1 mrad/h-μCi. The variation is attributable to differences in the distribution of the radium on the various watches in respect to the position of the five dosimeters.

Estimation of absorbed dose to gonads and other anatomical sites

The absorbed dose rate to remote sites of the human body from any the sample pocket watches would be relatively small in terms of the detection capability of TLD rods. Therefore, a simulated radium-activated watch of higher activity was required to estimate the absorbed dose to these sites using a sectioned human phantom. This watch was prepared by removing the hands and dial plate from a sample watch and attaching a platinum-encapsulated radium-226 needle at each of the 2:00, 4:00, 7:00, and 10:00 o'clock positions behind the crystal. Total radium content of the needles was 4.13 mCi.

TLD rods were inserted in the various sites within the phantom, and the watch was placed with its crystal facing inward on the crest of the phantom's iliac. After 6 hours, the TLD rods were removed and their absorbed dose measured. The absorbed dose rate was then calculated for each site (table 3). Annual absorbed dose rates normalized for a watch content of 1 μCi of radium for 16 hours a day were then calculated and also appear in table 3.

Conclusions

The radium content of the watches studied ranged from 0.60 to 1.39 μCi with an average of approximately 1 μCi. The data show that a watch containing 1 microcurie of radium would expose the gonads of a male to an annual dose of 60 millirads if worn for 16 hours daily while the skin directly under the face of the watch would receive an average dose of 165 rads.

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SECTION I. MILK AND FOOD

Milk Surveillance, September 1969

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation and/or corrective public health action.

The Pasteurized Milk Network, (PMN) sponsored by the Bureau of Radiological Health and the Bureau of Compliance, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations; 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiological Health Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Public Health Service)—5 sampling stations
Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations

The sampling locations that make up the networks presently reporting in *Radiological Health Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that occur in or are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both

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Figure 1. Milk sampling networks in the Western Hemisphere

calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variation, expressed in terms of 2-standard deviations, for these concentrations are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for the period, May 1963–March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Bureau of Radiological Health conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested public health radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted in December 1968, with 37 laboratories participating in an experiment on milk samples containing known concentrations of strontium-90, iodine-131 and cesium-137. Of the 19 laboratories producing data for the networks reporting in *Radiological Health Data and Reports*, 18 participated in the experiment.

In general, the results for iodine-131 and cesium-137 are encouraging, but the results for strontium-89 and strontium-90 need improvement (*5*). Keeping these possible differences in mind, integration of the data from the various networks can be undertaken without introducing a serious error due to disagreement among the independently obtained data.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methodologies, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140) are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports*.

A recent article (*6*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and earlier data articles for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. The frequency of collection and analysis varies not only among the networks, but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short time periods and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical, and is generally increased at the first measurement or recognition of a new influx of the radionuclide.

The data presentation also reflects whether raw or pasteurized milk was collected. A recent analysis (*7*) of raw and pasteurized milk samples collected during the period, January 1964 to June 1966, indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant. Particular attention was paid to strontium-90 and cesium-137 in that analysis.

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Practical reporting levels were developed by the participating networks, most often based on 2-standard deviation counting errors or 2-standard deviation total analytical errors from replicate analyses experiments (*3*). The practical reporting level reflects additional analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurement equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical errors of precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2-standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter
Iodine-131, Cesium-137, Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter

For iodine-131, cesium-137, and barium-140 there is one exception for these precision error ranges; 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiological Health Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environmental conditions is presented below. The function of the Council is to provide guidance to Federal agencies in the formulation of radiation standards.

Radiation Protection Guides (*8*, *9*)

The Radiation Protection Guide (RPG) has been defined by the Federal Radiation Council (FRC) as the radiation dose which should not be exceeded without careful consideration of the reasons for doing so; every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. An RPG provides radiation protection guidance for the control and regulation of normal peacetime uses of nuclear technology in which control is exercised primarily at the source through the design and use of nuclear material. It represents a balance between the possible risk to the general public that might result from exposures from routine uses of ionizing radiation and the benefits from the activities causing the exposure.

Table 1 presents a summary of guidelines and related information on environmental radiation levels as set forth by the FRC for the conditions under which RPG's are applicable. A more detailed discussion of these values was presented earlier (*3*).

In the absence of specific dietary data one can use milk as the indicator food item for routine surveillance. Assuming a 1-liter per day intake of milk, one can utilize the graded approach of daily intake on the basis of radionuclide content in milk samples collected to represent general population consumption. Under these assumptions, the radionuclide concentrations in pCi/liter of milk can replace the daily radionuclide intake in pCi/day in the three graded ranges.

Table 1. Radiation Protection Guides—FRC recommendations and related information pertaining to environmental levels during normal peacetime operation

Nuclide	Critical organ	RPG for individual in the general population (rad/a)	Guidance for suitable samples of exposed population group[a]				
			RPG (rad/a)	Corresponding continuous daily intake (pCi/day)	Range I (pCi/day)[b]	Range II (pCi/day)[b]	Range III (pCi/day)[b]
Strontium-89	Bone	[c]1.5	0.5	[d]2,000	0–200	200–2,000	2,000–20,000
	Bone marrow	[e].5	.17				
Strontium-90	Bone	[c]1.5	.5	[d]200	0–20	20–200	200–2,000
	Bone marrow	[e].5	.17				
Iodine-131	Thyroid	1.5	.5	100	0–10	10–100	100–1,000
Cesium-137[e]	Whole body	.5	.17	3,600	0–360	360–3,600	3,600–36,000

[a] Suitable samples which represent the limiting conditions for this guidance are: strontium-89, strontium-90—general population; iodine-131—children 1 year of age; cesium-137—infants.
[b] Based on an average intake of 1 liter of milk per day.
[c] A dose of 1.5 rad/a to the bone is estimated to result in a dose of 0.5 rad/a to the bone marrow.
[d] For strontium-89 and strontium-90, the Council's study indicated that there is currently no operational requirement for an intake value as high as one corresponding to the RPG. Therefore, these intake values correspond to doses to the critical organ not greater than one-third the respective RPG.
[e] The guides expressed here were not given in the FRC reports, but were calculated using appropriate FRC recommendations.

Protective Action Guides (*10, 11*)

The Protective Action Guide (PAG) has been defined by the Council as the projected absorbed dose to individuals in the general population that warrants protective action following a contaminating event. A PAG provides general guidance for the protection of the population against exposure by ingestion of contaminated foods resulting from the accidental release or the unforeseen dispersal of radioactive materials in the environment. A PAG is also based on the assumption that such an occurrence is an unlikely event, and circumstances that might involve the probability of repetitive occurrences during a one or two year period in a particular area would require special consideration. Protective actions are appropriate when the health benefits associated with the reduction in exposure to be achieved are sufficient to offset the undesirable features of the protective actions.

Table 2 presents a summary of guidelines as set forth by the FRC for the conditions under which PAG's are applicable. A more detailed discussion of these values was presented earlier (*3*). Also given in table 2 are milk concentrations for each of the radionuclides considered, in the absence of others, which if attained after an acute incident, would result in doses equivalent to the appropriate PAG. These concentrations are based on a projection of the maximum concentration from an idealized model for any acute deposition and the pasture-cow-milk-man pathway, as well as an estimate of the intake prior to reaching the maxi-

Table 2. Protective Action Guides—FRC recommendations and related information pertaining to environmental levels during an acute contaminating event

Radionuclide	Critical organ	PAG for individuals in general population (rads)	Category (pasture-cow-milk)	
			Guidance for suitable sample, children 1 year of age	
			PAG (rads)	Maximum concentration in milk for single nuclide that would result in PAG (pCi/liter)
Strontium-89	Bone marrow	10 in first yr; total dose not to exceed 15[a,b]	3 in first yr; total dose not to exceed 5[a,b]	[c]1,110,000
Strontium-90	Bone marrow			[c]51,000
Cesium-137	Whole body			[c]720,000
Iodine-131	Thyroid	30	10	[d]70,000

[a] The sum of the projected doses of these three radionuclides to the bone marrow should be compared to the numerical value of the respective guide.
[b] Total dose from strontium-89 and cesium-137 is the same as dose in first year; total dose from strontium-90 is 5 times strontium-90 dose in first year for children approximately 1 year of age.
[c] These values represent concentrations that would result in doses to the bone marrow or whole body equal to the PAG, if only the single radionuclide were present.
[d] This concentration would result in the PAG dose based on intake before and after the date of maximum concentration observed in milk from an acute contaminating event. A maximum of 84,000 pCi/liter would result in a PAG dose if that portion of intake prior to the maximum concentration in milk is not considered. Children, 1 year of age, are assumed to be the critical segment of the population.

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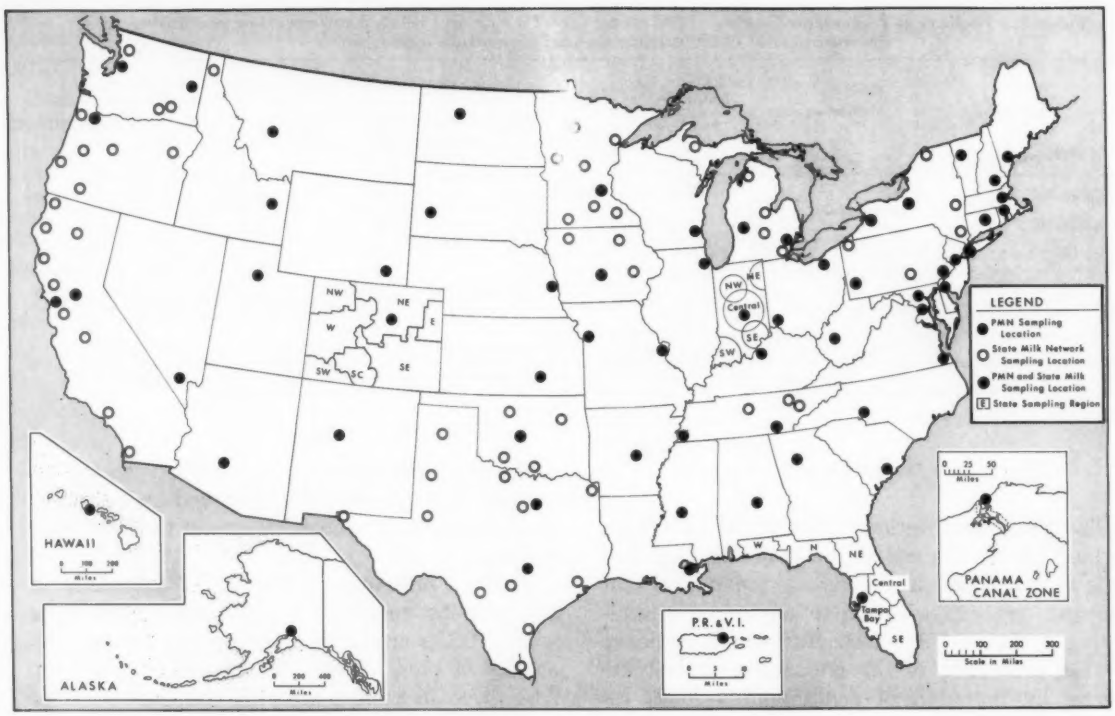

Figure 2. State and PMN milk sampling locations in the United States

mum concentration. Therefore, these maximum concentrations are intended for use in estimating future intake on the basis of a few early samples rather than in retrospective manner.

Data reporting format

Table 3 presents the integrated results of the international, national and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiological Health Data and Reports*. (The relationship between the PMN stations and State stations is shown in figure 2). The first column under each of the radionuclides reported gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12-monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 3, surveillance results are given for strontium-89, strontium-90, iodine-131, and cesium-137 for September 1969 and the 12-month period, October 1968–September 1969. Except where noted the monthly average represents a single sample for the sampling station. Barium-140 data have been omitted from table 3 since levels at the great majority of the stations for September 1969 were below the respective practical reporting levels with the exception of Erie, Pa., 17 pCi/liter, 1 sample.

Table 3. Concentration of radionuclides in milk for September 1969 and 12-month period, October 1968 through September 1969

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)							
			Strontium–89		Strontium–90		Iodine–131		Cesium–137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:										
Ala:	Montgomery[c]	P	0 (2)	1	5 (2)	6	0 (4)	0	11 (4)	11
Alaska:	Palmer[c]	P	0	0	6	6	0 (4)	0	0 (4)	8
Ariz:	Phoenix[c]	P	0	0	0	1	0 (4)	0	0 (4)	0
Ark:	Little Rock[c]	P	3 (2)	1	15 (2)	18	0 (5)	0	14 (5)	18
Calif:	Sacramento[c]	P	0	0	0	2	0 (4)	0	0 (4)	1
	San Francisco[c]	P	0	0	3	2	0 (4)	0	0 (4)	0
	Del Norte	P	11	1	18	19	0	0	17	16
	Fresno	P	0	0	0	0	0	0	5	1
	Humboldt	P	0	2	4	5	0	0	8	8
	Los Angeles	P	0	0	0	0	0	0	0	1
	Mendocino	P	0	0	3	3	0	0	2	1
	Sacramento	P	0	0	3	3	0	0	2	1
	San Diego	P	0	0	0	0	0	0	1	1
	Santa Clara	P	0	0	0	0	0	0	6	3
	Shasta	P	0	0	4	3	0	0	5	4
	Sonoma	P	0	0	3	2	0	0	4	0
Colo:	Denver[c]	P	0	2	6	5	0 (4)	0	0 (4)	2
	West	R	[d]		[d]		[e] (13)	[e]	[e] (13)	[e]
	Northeast	R	[d]		[d]		[e] (2)	[e]	[e] (2)	[e]
	East	R	[d]		[d]		[e]	[e]	[e]	[e]
	Southeast	R	[d]		[d]		[e]	[e]	[e] (3)	[e]
	South Central	R	[d]		[d]		NS	[e]	NS	[e]
	Southwest	R	[d]		[d]		[e]	[e]	[e]	[e]
	Northwest	R	[d]		[d]		[e]	[e]	[e] (2)	[e]
Conn:	Hartford[c]	P	6	3	7	8	0 (3)	0	10 (3)	12
	Central	P	0	0	8	7	0 (4)	0	12 (4)	11
Del:	Wilmington[c]	P	7	3	6	8	0 (4)	0	3 (4)	7
D.C:	Washington[c]	P	3 (2)	1	6 (2)	8	0 (4)	0	4 (4)	4
Fla:	Tampa[c]	P	4 (2)	0	5 (2)	7	0 (4)	0	61 (4)	60
	West	R	[d]		11	12	0	0	23	23
	North	R	[d]		10	14	0	0	23	35
	Northeast	R	[d]		9	8	0	0	66	66
	Central	R	[d]		10	8	0	0	58	57
	Tampa Bay area	R	[d]		9	8	0	1	62	64
	Southeast	R	[d]		8	9	0	0	98	96
Ga:	Atlanta[c]	P	0 (2)	0	8 (2)	10	0 (4)	0	24 (4)	19
Hawaii:	Honolulu[c]	P	0 (4)	0	3 (4)	3	0 (4)	0	0 (4)	0
Idaho:	Idaho Falls[c]	P	0	1	5	5	0 (5)	0	3 (5)	7
Ill:	Chicago[c]	P	0	2	6	8	0 (5)	0	12 (5)	10
Ind:	Indianapolis[c]	P	0	0	7	8	0 (5)	0	1 (5)	6
	Northeast	P	0	0	10	12	0	0	20	10
	Southeast	P	0	0	10	8	0	0	10	10
	Central	P	0	0	8	10	0	0	10	10
	Southwest	P	0	0	12	10	0	0	10	10
	Northwest	P	0	0	10	10	0	0	20	20
Iowa:	Des Moines[c]	P	0	1	6	6	0 (4)	0	0 (4)	3
	Iowa City	P	NS		NS		NS		NS	
	Des Moines	P	NS		NS		NS		NS	
	Spencer	P	NS		NS		NS		NS	
	Fredericksburg	P	NS		NS		NS		NS	
Kans:	Wichita[c]	P	7	2	5	7	0 (5)	0	0 (5)	2
Ky:	Louisville[c]	P	3 (2)	2	9 (2)	10	0 (5)	0	2 (5)	6
La:	New Orleans[c]	P	0 (2)	2	15 (2)	17	0 (3)	0	19 (3)	20
Maine:	Portland[c]	P	0	0	14	12	0 (4)	0	24 (4)	25
Md:	Baltimore[c]	P	4 (2)	1	7 (2)	9	0 (5)	1	3 (5)	7
Mass:	Boston[c]	P	0	1	11	11	0 (5)	0	21 (5)	21
Mich:	Detroit[c]	P	0	0	9	8	0 (5)	0	7 (5)	9
	Grand Rapids[c]	P	0	0	9	10	0 (5)	0	15 (5)	14
	Bay City	P	[d]		NS	NA	NS	[e]	NS	11
	Charlevoix	P	[d]		8	10	[e] (4)	[e]	24 (4)	17
	Detroit	P	[d]		5	5	[e] (5)	[e]	7 (5)	5
	Grand Rapids	P	[d]		5	7	[e] (5)	[e]	14 (5)	11
	Lansing	P	[d]		7	6	[e] (2)	[e]	14 (2)	9
	Marquette	P	[d]		8	9	[e] (3)	[e]	24 (3)	28
	Monroe	P	[d]		5	4	[e] (2)	[e]	0 (2)	1
	South Haven	P	[d]		NS	7	NS	[e]	NS	8
Minn:	Minneapolis[c]	P	0	2	10	10	0 (5)	0	10 (5)	11
	Bemidji	P	[d]		17	17	0	0	26	24
	Mankato	P	[d]		9	8	0	0	0	0
	Rochester	P	[d]		8	9	0	0	0	0
	Duluth	P	[d]		17	19	0	0	25	25
	Worthington	P	[d]		7	8	0	0	0	0
	Minneapolis	P	[d]		12	12	0	0	0	0
	Fergus Falls	P	[d]		11	9	0	0	0	0
	Little Falls	P	[d]		9	10	0	0	0	12
Miss:	Jackson[c]	P	3 (2)	1	11 (2)	13	0 (4)	0	15 (4)	16
Mo:	Kansas City[c]	P	0	4	8	7	0 (3)	0	1 (3)	2
	St. Louis	P	8	2	7	8	0 (4)	0	0 (4)	3
Mont:	Helena[c]	P	0	1	5	5	0 (5)	0	3 (5)	6
Nebr:	Omaha[c]	P	0	3	5	6	0 (5)	0	0 (5)	2

See footnotes at end of table.

Table 3. Concentration of radionuclides in milk for September 1969 and 12-month period, October 1968 through September 1969—Continued

Sampling location		Type of sample[a]	Radionuclide concentration (pCi/liter)							
			Strontium–89		Strontium–90		Iodine–131		Cesium–137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average	M9nthly average[b]	12-month average
UNITED STATES:— Continued										
Nev:	Las Vegas[c]	P	0	0	0	1	0 (5)	0	0 (5)	0
N.H:	Manchester[c]	P	0	0	6	9	0 (5)	0	15 (5)	22
N.J:	Trenton[c]	P	0	0	9	9	0 (4)	0	1 (4)	8
N.Mex:	Albuquerque[c]	P	0	0	3	2	0 (5)	0	3 (5)	1
N.Y:	Buffalo[c]	P	0 (2)	0	7 (2)	7	0 (4)	0	4 (4)	9
	New York City[c]	P	0	0	12	10	0 (5)	0	11 (5)	13
	Syracuse[c]	P	0	0	8	8	0 (5)	0	13 (5)	9
	Albany	P	0	0	0	6	0 (3)	0	0 (2)	0
	Buffalo	P	0	0	0	5	0	0	0	0
	Massena	P	5	0	3	10	0 (2)	0	0 (2)	0
	Newburg	P	10	0	0	10	0	0	0	0
	New York City	P	0	0	9	11	0 (4)	0	0 (5)	0
	Syracuse	P	0	0	7	7	0 (2)	0	0 (2)	0
N.C:	Charlotte[c]	P	0 (2)	1	10 (2)	14	0 (5)	0	9 (5)	12
N.Dak:	Minot[c]	P	14	6	8	10	0 (5)	0	10 (5)	12
Ohio:	Cincinnati[c]	P	0	0	9	8	0 (4)	0	0 (4)	3
	Cleveland[c]	P	0	0	9	8	0 (4)	0	4 (4)	7
Okla:	Oklahoma City[c]	P	4 (2)	1	7 (2)	8	0 (5)	0	11 (5)	10
	Oklahoma City	P	NS		NS		NS		NS	
	Enid	P	NS		NS		NS		NS	
	Tulsa	P	NS		NS		NS		NS	
	Lawton	P	NS		NS		NS		NS	
	Ardmore	P	NS		NS		NS		NS	
Ore:	Portland[c]	P	0	2	9	7	0 (4)	0	9 (4)	7
	Baker	P	(d)		0	2	(e)	(e)	(e)	8
	Coos Bay	P	(d)		0	6	(e)	(e)	(e)	11
	Eugene	P	(d)		0	4	(e)	(e)	(e)	8
	Medford	P	(d)		0	2	(e)	(e)	33	19
	Portland composite	P	(d)		0	3	(e)	(e)	(e) (4)	6
	Portland local	P	(d)		2	4	(e)	(e)	(e) (4)	10
	Redmond	P	(d)		0	2	(e)	(e)	(e)	5
	Tillamook	R	(d)		0	5	(e)	(e)	21	21
Pa:	Philadelphia[c]	P	0	0	10	9	0 (4)	0	3 (4)	5
	Pittsburgh[c]	P	0	0	11	12	0 (5)	0	10 (5)	8
	Dauphin	P	(d)		6	7	0	1	19	14
	Erie	P	(d)		11	11	26	5	19	18
	Philadelphia	P	(d)		10	9	0	0	5	12
	Pittsburgh	P	(d)		11	10	0	1	14	16
R.I:	Providence[c]	P	0	0	10	9	0 (5)	0	15 (5)	17
S.C:	Charleston[c]	P	0 (2)	0	10 (2)	11	0 (5)	0	25 (5)	24
S.Dak:	Rapid City[c]	P	9	5	8	8	0 (5)	0	3 (5)	6
Tenn:	Chattanooga[c]	P	4	2	9 (2)	11	0 (5)	0	10 (5)	13
	Memphis[c]	P	0	1	9 (2)	9	0 (4)	0	0 (4)	6
	Chattanoogn	P	0	4	13	13	0 (4)	0	15	15
	Clinton	P	0	1	12	15	0 (2)	1	15	14
	Knoxville	P	0	1	10	10	0	0	13	8
	Nashville	P	NS	3	NS	9	NS	0	NS	5
Tex:	Austin[c]	P	4 (2)	1	0 (2)	2	0 (2)	0	0 (2)	4
	Dallas[c]	P	3 (2)	1	5 (2)	7	0 (5)	0	5 (5)	7
	Amarillo	R	(d)		5	4	0	0	0	0
	Corpus Christi	R	(d)		NS	4	NS	0	NS	0
	El Paso	R	(d)		NS	2	NS	0	NS	0
	Fort Worth	R	(d)		NS	6	NS	0	NS	0
	Harlingen	R	(d)		2	2	0	0	0	0
	Houston	R	(d)		NS	7	NS	0	NS	19
	Lubbock	R	(d)		NS	3	NS	0	NS	0
	Midland	R	(d)		NS	2	NS	0	NS	0
	San Antonio	R	(d)		2	3	0	0	0	0
	Texarkana	R	(d)		NS	11	NS	0	NS	10
	Uvalde	R	(d)		NS	1	0	0	NS	0
	Wichita Falls	R	(d)		NS	6	0	0	0	5
Utah:	Salt Lake City[c]	P	0	1	5	4	0 (5)	0	6 (5)	7
Vt:	Burlington[c]	P	0	0	7	8	0 (5)	0	18 (5)	14
Va:	Norfolk[c]	P	0 (2)	0	11 (2)	10	0 (4)	0	9 (4)	7
Wash:	Seattle[c]	P	0	1	8	8	0 (4)	0	13 (4)	15
	Spokane[c]	P	0	1	6	6	0 (5)	0	6 (5)	5
	Benton County	R	(d)		0	1	0	0	12	5
	Franklin County	R	NS		NS	1	NS	0	NS	0
	Sandpoint, Idaho	R	(d)		10	11	0	0	38	28
	Skagit County	R	(d)		10	7	0	0	36	14
W.Va:	Charleston[c]	P	0 (2)	1	8 (2)	9	0 (4)	0	0 (4)	8
Wisc:	Milwaukee[c]	P	0	0	6	7	0 (4)	0	7 (4)	12
Wyo:	Laramie[c]	P	6	1	3	5	0 (4)	0	1 (4)	10

See footnotes at end of table.

Table 3. Concentration of radionuclides in milk for September 1969 and 12-month period, October 1968 through September 1969—Continued

Sampling location	Type of sample[a]	Radionuclide concentration (pCi/liter)							
		Strontium–89		Strontium–90		Iodine–131		Cesium–137	
		Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA:									
Alberta: Calgary	P	[d]		9	8	[d]		15	16
Edmonton	P	[d]		6	7	[d]		15	15
British Columbia: Vancouver	P	[d]		9	12	[d]		34	36
Manitoba: Winnipeg	P	[d]		8	9	[d]		21	25
New Brunswick: Fredericton	P	[d]		15	14	[d]		16	19
Newfoundland: St. Johns	P	[d]		29	18	[d]		54	37
Nova Scotia: Halifax	P	[d]		10	10	[d]		20	20
Ontario: Ft. William	P	[d]		11	16	[d]		28	31
Ottawa	P	[d]		8	9	[d]		16	16
Sault Ste. Marie	P	[d]		13	16	[d]		34	31
Toronto	P	[d]		3	5	[d]		9	13
Quebec: Windsor	P	[d]		6	6	[d]		6	12
Montreal	P	[d]		7	9	[d]		22	18
Quebec	P	[d]		11	11	[d]		33	27
Saskatchewan: Regina	P	[d]		8	7	[d]		15	14
Saskatoon	P	[d]		10	8	[d]		15	14
CENTRAL AND SOUTH AMERICA:									
Columbia: Bogota	P	0	10	1	1	0	0	0	1
Chile: Santiago	P	0	4	2	0	0	0	10	1
Ecuador: Guayaquil	P	0	3	0	0	0	0	0	0
Jamaica: Montego Bay	P	10	3	7	5	0	0	260	100
Venezuela: Caracas	P	0	2	3	1	0	0	0	0
Canal Zone: Cristobal[e]	P	0 (2)	2	1 (2)	1	0 (5)	0	11 (5)	13
Puerto Rico: San Juan[e]	P	3 (2)	1	3 (2)	4	0 (4)	0	0 (4)	7
PMN Network average[f]		2	1	7	8	0	0	7	10

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] PHS Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] Radionuclide analysis not routinely performed.

[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:

Iodine–131: Colorado–25 pCi/liter; Michigan–14 pCi/liter; Oregon–15 pCi/liter
Cesium–137: Colorado–25 pCi/liter; New York–20 pCi/liter; Washington–15 pCi/liter

[f] This entry gives the average radionuclide concentration for the PHS Pasteurized Milk Network stations denoted by footnote [e].

NA, no analysis.
NS, no sample collected.

Iodine-131 results are included in the table, even though they were generally below practical reporting levels. Because of the lower values reflected by the radiation protection guidance provided by the Federal Radiation Council (table 1), levels in milk for this radionuclide are of particular public health interest. In general, the practical reporting level for iodine-131 is numerically equal to the upper value of Range I (10 pCi/liter) of the FRC radiation protection guide.

Iodine-131 monthly averages were all below the practical reporting level with the exception of Erie, Pa., 26 pCi/liter, 1 sample, and Clinton, Tenn. 5 pCi/liter, 2 samples.

Strontium-89 monthly averages ranged from 0 to 14 pCi/liter in the United States for the month of September 1969 and the highest 12-month average was 6 pCi/liter (Minot, N. Dak.) representing 0.3 percent of the recommended guide (table 1). Strontium-90 monthly averages ranged

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from 0 to 18 pCi/liter for the month of September 1969 and the highest 12-month average was 19 pCi/liter (Del Norte, Calif., and Duluth, Minn.) representing 9.5 percent of the recommended guide (table 1), Cesium-137 monthly averages ranged from 0 to 98 pCi/liter in the United States for the month of September 1969 and the highest 12-month average was 96 pCi/liter (southeast Florida), representing 2.7 percent of the value presented in this report using the recommendations given in the Federal Radiation Council reports. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*12*) and Jamaica.

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Radiological Health Section
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Colorado State Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Division of Radiological Health
Bureau of Preventable Diseases
Florida State Board of Health

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiological Health Service
Division of Occupational Health
Michigan Department of Health

Radiation Protection Division
Canadian Department of National Health and Welfare

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Health
Division of Environmental Health Services
New York State Department of Health

Division of Occupational and Radiological Health
Environmental Health Services
Oklahoma State Department of Health

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Office of Air Quality Control
Division of Technical Services
Washington State Department of Health

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Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are as follows.

Program	Period reported	Issue
California Diet Study	November 1967–September 1968	May 1969
Connecticut Diet Study	January–June 1968	November 1968
Strontium-90 in Tri-City Diets	August–December 1968	December 1969

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1. Radionuclides in Institutional Diet Samples April June 1969

Bureau of Radiological Health

The determination of radionuclide concentrations in the diet constitutes an important element of an integrated program of environmental radiological surveillance and assessment. In recognition of the potential significance of the diet in contributing to total environmental radiation exposures, the Public Health Service initiated its Institutional Total Diet Sampling Network in 1961. This program is administered by the Bureau of Radiological Health with the assistance of the Bureau of Compliance, Food and Drug Administration (*1*).

The program was designed to provide estimates of the dietary intake of radionuclides in a selected population group ranging from children to young adults of school age. Initially, the program was conducted at eight institutions; as of January 1965, its scope had increased to boarding schools or institutions in 50 municipalities. These institutions ranged from financially well-to-do boarding schools to orphanages with severe economic limitations.

Subsequent experience with the diets of school children of various ages indicated that the number of institutions sampled could be selectively reduced. As of July 1965, 21 basic institutions and eight auxiliary institutions distributed geographically as shown in figure 1, were being sampled. Previous results showed that the daily dietary intake of teenage girls and children from 9 to 12 years of age were comparable, while teenage boys consumed 20 percent more food per day (*1*, *2*). Consequently, estimates for teenage boys or girls can be calculated on the basis of the dietary intakes of children.

In general, the sampling procedure is the same at each institution. Each sample represents the edible portion of the diet for a full 7-day week, (21 meals plus soft drinks, candy bars, or other in-between snacks) obtained by duplicating the meals of a different individual each day. Drinking water, not included in the samples, is also sampled periodically. Each daily sample is kept frozen until the end of the collection period and is then packed in dry ice and shipped by air express to either the

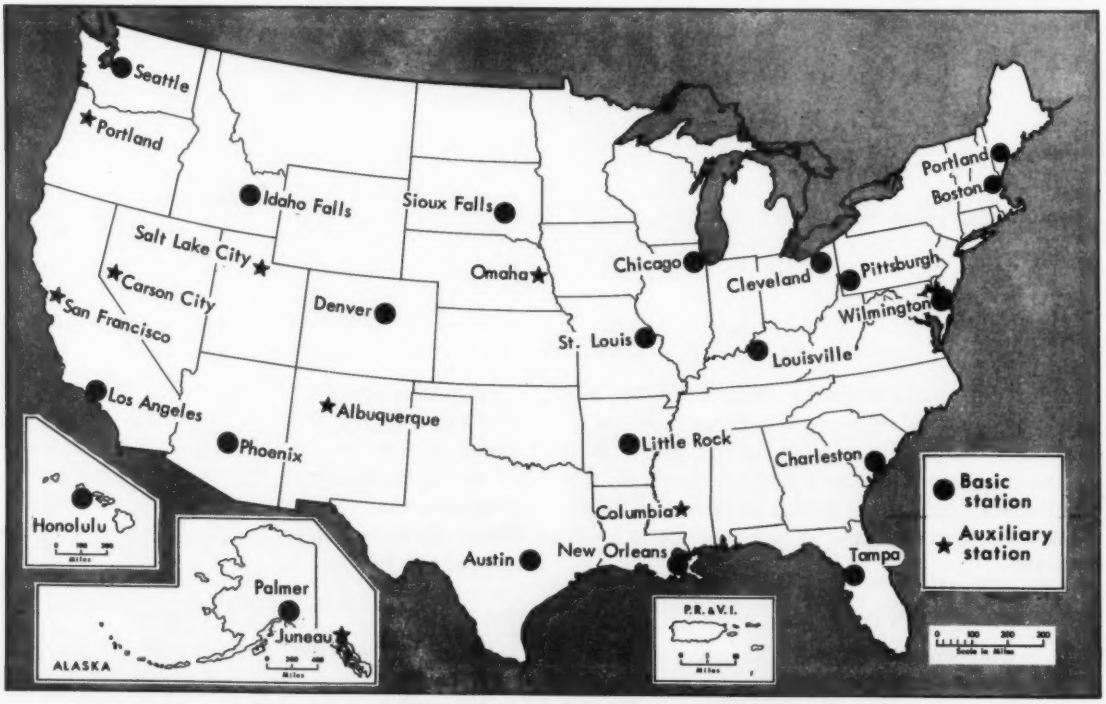

Figure 1. Institutional diet sampling locations as of June 1969

Southwestern Radiological Health Laboratory, Las Vegas, Nev; the Southeastern Radiological Health Laboratory, Montgomery, Ala; or the Northeastern Radiological Health Laboratory, Winchester, Mass. A detailed description of sampling and analytical procedures was presented earlier. (*3*)

Results

Table 1 presents the analytical results for institutional diet samples collected from April through June 1969, for children 9 to 12 years of age. The stable elements, calcium and potassium, are reported in g/kg of diet, and the radionuclide concentrations of these samples reported in pCi/kg

Table 1. Concentration and intake of stable elements and radionuclides in Institutional total diets of children (9–12 years of age), April–June 1969

Location of Institution	Month (1969)	Total weight (kg/day)	Calcium		Potassium		^{89}Sr		^{90}Sr		^{137}Cs		^{226}Ra	
			(g/kg)	(g/day)	(g/kg)	(g/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)
Alaska: Palmer	April[a]	1.21	0.81	0.98	2.0	2.4	0	0	8	9	14	17	0.5	0.6
	May	1.59	.44	.70	1.0	1.6	0	0	6	10	0	0	.3	.5
	June	1.66	.50	.83	1.1	1.7	0	0	3	5	0	0	.5	.8
Ariz: Phoenix	April	1.81	.50	.91	1.3	2.3	0	0	3	5	0	0	.4	.7
	May	1.89	.52	.98	1.4	2.6	0	0	2	5	0	0	.4	.8
	June	1.78	.38	.68	1.3	2.2	0	0	0	0	0	0	.3	.5
Ark: Little Rock	April	1.56	.56	.87	1.4	2.2	NA	NA	8	12	0	0	.7	1.1
	May	1.33	.58	.77	1.9	2.5	NA	NA	7	9	22	29	.6	.8
	June	1.11	.33	.37	1.0	1.1	NA	NA	5	5	12	13	.4	.4
Calif: Los Angeles	April[a]	1.53	.37	.57	1.2	1.9	0	0	0	0	0	0	.4	.6
	May[a]	1.78	.34	.61	.9	1.6	0	0	3	5	0	0	.5	.9
	June[a]	1.58	.50	.79	1.3	2.0	0	0	0	0	0	0	.5	.8
Colo: Denver	April	2.25	.79	.78	1.4	3.2	0	0	7	15	0	0	.7	.6
	May	2.19	.66	.45	1.3	2.8	0	0	6	12	0	0	.7	1.5
	June	NS												
Del: Wilmington	April	2.21	.71	.57	1.6	3.5	NA	NA	5	11	0	0	.7	1.5
	May	NS												
	June	2.31	.65	1.50	1.7	3.9	NA	NA	6	14	19	44	.6	1.4
Fla: Tampa	April	1.19	.49	.58	1.3	1.6	NA	NA	6	7	18	21	.9	1.1
	May	1.26	.57	.72	1.5	1.9	NA	NA	7	9	26	33	.6	.8
	June	1.26	.46	.58	1.4	1.8	NA	NA	6	7	38	48	.8	1.0
Hawaii: Honolulu	April	2.86	.39	1.12	1.4	3.9	0	0	6	16	11	31	.3	.9
	May	2.86	.36	1.03	1.3	3.7	0	0	4	11	0	0	.4	1.1
	June	2.41	.49	1.18	1.4	3.4	0	0	4	10	23	55	.4	1.0
Idaho: Idaho Falls	April[a]	2.21	.08	2.39	1.8	4.0	0	0	7	15	13	29	.5	1.1
	May[a]	1.97	.29	2.54	1.6	3.2	NA	NA	9	18	0	0	.7	1.4
	June[a]	2.10	.06	2.23	1.8	3.8	NA	NA	7	15	0	0	.7	1.5
Ky: Louisville	April	1.89	.79	1.49	1.7	3.1	NA	NA	11	20	0	0	.6	1.1
	May	2.07	.80	1.66	1.7	3.5	NA	NA	9	19	0	0	.5	1.0
	June	1.90	.82	1.56	1.5	2.9	NA	NA	10	19	12	23	.5	1.0
La: New Orleans	April	1.99	.63	1.25	1.7	3.4	0	0	12	23	0	0	.3	.6
	May	2.01	.59	1.19	1.7	3.5	0	0	11	23	0	0	.5	1.0
	June	2.10	.55	1.16	1.5	3.2	0	0	9	20	18	38	.4	.8
Maine: Portland	April	1.70	.84	1.43	1.9	3.2	NA	NA	11	19	31	53	.7	1.2
	May	1.91	.82	1.57	1.8	3.4	NA	NA	13	25	36	69	.5	1.0
	June	1.53	.60	.92	1.8	2.8	NA	NA	12	18	41	63	.5	.8
Mass: Boston	April	2.08	.59	1.23	1.7	3.5	0	0	6	12	17	35	.5	1.0
	May	2.04	.62	1.26	1.8	3.7	0	0	7	14	22	45	.7	1.4
	June	2.13	.64	1.36	1.8	3.8	0	0	10	21	20	43	.7	1.5
Mo: St. Louis	April[a]	2.49	1.42	3.54	1.8	4.5	NA	NA	15	37	0	0	2.3	5.7
	May[a]	2.55	1.38	3.52	1.8	4.6	NA	NA	10	26	0	0	.8	2.0
	June[a]	2.43	1.06	2.58	1.9	4.6	NA	NA	9	22	12	29	.7	1.7
Ohio: Cleveland	April	1.49	.76	1.13	1.9	2.8	NA	NA	7	10	14	21	1.0	1.5
	May	1.56	.66	1.03	1.8	2.8	NA	NA	6	9	0	0	.7	1.1
	June	1.44	.67	.96	1.8	2.6	NA	NA	6	9	0	0	.5	.7
Pa: Pittsburgh	April	2.24	.53	1.19	1.4	3.1	NA	NA	8	18	0	0	.7	1.6
	May	2.26	.55	1.24	1.5	3.4	NA	NA	7	16	0	0	.6	1.4
	June	2.20	.53	1.17	1.5	3.3	NA	NA	8	18	11	24	.6	1.3
S.C: Charleston	April	1.72	.66	1.14	1.4	2.4	0	0	8	14	17	29	.6	1.0
	May	1.45	.76	1.10	1.6	2.4	0	0	12	17	16	23	.6	.9
	June	1.01	.49	.49	1.4	1.5	0	0	10	10	36	36	.6	.6
S.Dak: Sioux Falls	April	1.39	.75	1.04	1.5	2.1	NA	NA	7	10	0	0	.9	1.3
	May	1.42	.67	.95	1.5	2.1	NA	NA	6	9	0	0	1.0	1.4
	June	1.35	.80	1.08	1.5	2.0	NA	NA	8	11	11	15	.6	.8
Tex: Austin	April[a]	1.92	.68	1.31	1.5	2.8	NA	NA	4	8	0	0	.4	.8
	May[a]	1.85	.80	1.48	1.4	2.7	NA	NA	4	7	0	0	.4	.7
	June[a]	2.02	.94	1.90	1.5	3.0	NA	NA	4	7	0	0	.3	.6
Wash: Seattle	April[a]	2.02	.54	1.09	1.5	3.0	0	0	4	8	0	0	.6	1.2
	May[a]	1.98	.50	.99	1.6	3.2	0	0	4	7	17	34	.4	.8
	June[a]	1.93	.52	1.00	1.5	2.8	0	0	6	11	0	0	.5	1.0
Institutional average	April	1.88	0.64	1.19	1.5	2.9	0	0	7	14	8	14	0.6	1.2
	May	1.85	0.61	1.11	1.6	2.8	0	0	7	13	9	14	0.6	1.0
	June	1.73	0.57	0.99	1.5	2.6	0	0	7	12	17	29	0.5	0.9

[a] Since food samples were collected from two or more children who were not between the ages of 9 to 12, data for this month were not used in institutional average.
NA, no analysis.
NS, no sample.

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of diet, are corrected for radioactive decay to the midpoint of the sample collection period, where applicable. Dietary intakes, in g/day or pCi/day were obtained by multiplying the food consumption rate in kg/day by the appropriate concentration values. The average food consumption rate during this period was 1.96 kg/day compared to the network average of 1.87 kg/day observed from 1961 through 1968.

Strontium-90 dietary intake during this period averaged 13 pCi/day. This result falls within Range I as defined by the Federal Radiation Council (4). Cesium-137 intakes averaged 22 pCi/day during this period. Strontium–89, iodine–131, and barium–140 concentrations were generally below detectable levels.

All concentrations that are less than or equal to the appropriate minimum detectable level will be reported as zero. The minimum detectable concentration is defined as the measured concentration equal to the 2-standard deviation analytical error. Accordingly, the minimum detectable limits are as follows:

Strontium-89	5 pCi/kg
Strontium-90	2 pCi/kg
Iodine-131	10 pCi/kg
Cesium-137	10 pCi/kg
Barium-140	10 pCi/kg
Radium-226	0.1 pCi/kg

Data from eight auxiliary stations are included in a separate table for general information. This is presented in table 2. These stations do not meet the criterion that the majority of the samples are collected from children who range in age from 9 to 12 years. In order to supplement the existing environmental monitoring networks of the Bureau of Radiological Health, these eight institutions are being sampled in the same manner as the basic stations.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1968	April 1969
October–December 1968	July 1969
January–March 1969 and Annual Summary 1968	October 1969

REFERENCES

(1) ANDERSON, E. C., D. J. NELSON, JR. Surveillance for radiological contamination in foods. Amer J Public Health 52:1391–1400 (September 1962).

(2) PUBLIC HEALTH SERVICE, DIVISION OF RADIOLOGICAL HEALTH. Radionuclides in institutional total diet samples, January–March 1965. Radiol Health Data 6:548–554 (October 1965).

(3) PUBLIC HEALTH SERVICE, NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Radionuclides in Institutional total diet samples, January–March 1968. Radiol Health Data Rep 9:557–560 (October 1968).

(4) FEDERAL RADIATION COUNCIL. Background material for the development of radiation protection standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Table 2. Concentration and intake of stable elements and radionuclides in Institutional total diets of individuals (auxiliary stations), April–June 1969

Location of Institution	Month (1969)	Total weight (kg/day)	Calcium		Potassium		^{89}Sr		^{90}Sr		^{137}Cs		^{226}Ra	
			(g/kg)	(g/day)	(g/kg)	(g/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)	(pCi/kg)	(pCi/day)
Alaska: Juneau	April	1.18	0.62	0.73	1.3	1.5		0	5	6	11	13	0.4	0.5
	May	1.44	.84	1.21	1.7	2.5		0	7	10	0	0	6	.9
	June	1.25	.46	.58	1.4	1.8	0	0	7	9	45	56	.5	.6
Calif: San Francisco	April	2.29	.58	1.33	1.2	2.7	0	0	3	6	15	34	.4	.9
	May	2.23	.47	1.05	1.3	2.8	0	0	6	12	0	0	.6	1.3
	June	2.17	.48	1.04	1.5	3.3	0	0	4	10	0	0	.3	.7
Miss: Columbia	April	2.04	1.10	2.24	1.5	3.1	NA	NA	10	20	14	29	.6	1.2
	May	2.17	1.07	2.32	1.7	3.8	NA	NA	13	28	19	41	.6	1.3
	June	2.24	.85	1.90	1.7	3.8	NA	NA	12	26	16	36	.6	1.3
Nebr: Omaha	April	2.34	.79	1.85	1.7	4.0	NA	NA	5	12	0	0	.9	2.1
	May	2.39	1.00	2.39	1.7	4.1	NA	NA	7	17	12	29	.8	1.9
	June	2.34	.80	1.87	1.8	4.2	NA	NA	7	16	0	0	.6	1.4
Nev: Carson City	April	1.89	.74	1.40	1.0	1.9	0	0	0	0	0	0	.4	.8
	May	1.62	.58	.94	1.2	1.9	0	0	4	6	0	0	.5	.8
	June	1.41	.37	.52	1.3	1.8	0	0	3	4	0	0	.3	.4
N.Mex: Albuquerque	April	2.83	.86	2.43	1.5	4.4	NA	NA	3	7	0	0	.5	1.4
	May	2.60	.68	1.77	1.4	3.5	NA	NA	2	5	0	0	.3	.8
	June	2.35	.90	2.12	1.6	3.7	NA	NA	4	9	11	26	.4	.9
Ore: Portland	April	1.45	.49	.71	1.7	2.4	0	0	4	6	0	0	.4	.6
	May	2.28	.50	1.14	1.8	4.1	0	0	6	13	0	0	.6	1.4
	June	1.81	.54	.98	1.9	3.4	0	0	5	9	0	0	.5	.9
Utah: Salt Lake City	April	1.97	.52	1.02	1.2	2.3	0	0	4	8	0	0	.5	1.0
	May	2.40	.50	1.20	1.1	2.5	0	0	3	7	0	0	.3	.7
	June	2.41	.55	1.33	1.3	3.1	0	0	0	0	0	0	.4	1.0
Institutional average	April	2.00	0.71	1.46	1.4	2.8	0	0	4	8	5	9	0.5	1.1
	May	2.14	0.71	1.50	1.5	3.1	0	0	6	12	4	9	0.5	1.1
	June	2.00	0.62	1.29	1.6	3.1	0	0	5	10	9	15	0.5	0.9

NA, no analysis.

SECTION II. WATER

The Public Health Service, the Federal Water Pollution Control Administration and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be set higher if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities recently reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	January–June 1968	December 1969
Colorado River Basin	1967	December 1968
Florida	1967	February 1969
New York	July–December 1968	September 1969
North Carolina	January–December 1967	May 1969
Radiostrontium in Tap Water, HASL	July–December 1968	November 1969
Washington	July 1967–June 1968	June 1969

REFERENCES

(*1*) U. S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies, Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

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Radioactivity in Minnesota Municipal Water Supplies[1] January-June 1969

Division of Environmental Sanitation
Minnesota Department of Health

The analysis of various Minnesota waters for radioactivity was initiated in 1956 as part of the Minnesota Water Pollution Control Program. This program was expanded in 1958 to include most of the municipal surface water supplies in the State, as well as selected lakes throughout the State.

As many as 25 surface streams and lakes involving 74 stations have been sampled. At present, nine surface streams and lakes used as municipal water supplies are sampled routinely (figure 1). "Grab" samples of raw and treated water are collected weekly at Hallock, East Grand Forks, Eveleth, Fairmont, and St. Paul and monthly at Crookston, International Falls and St. Cloud. Minneapolis tap water is analyzed weekly. No raw water is collected from the Minneapolis supply.

The samples are forwarded to the Division's laboratory, where they are analyzed for gross alpha and beta radioactivity. A 500-ml sample of water is evaporated into a 2-inch aluminum milk bottle lid planchet and counted in an internal-proportional gas flow counter. Counter standardization is accomplished by adding known

[1] Data and information from "Survey of Environmental Radioactivity, January–June 1969." State of Minnesota Department of Public Health, University Campus, Minneapolis, Minn. 55440, Publication No. COO–651–81.

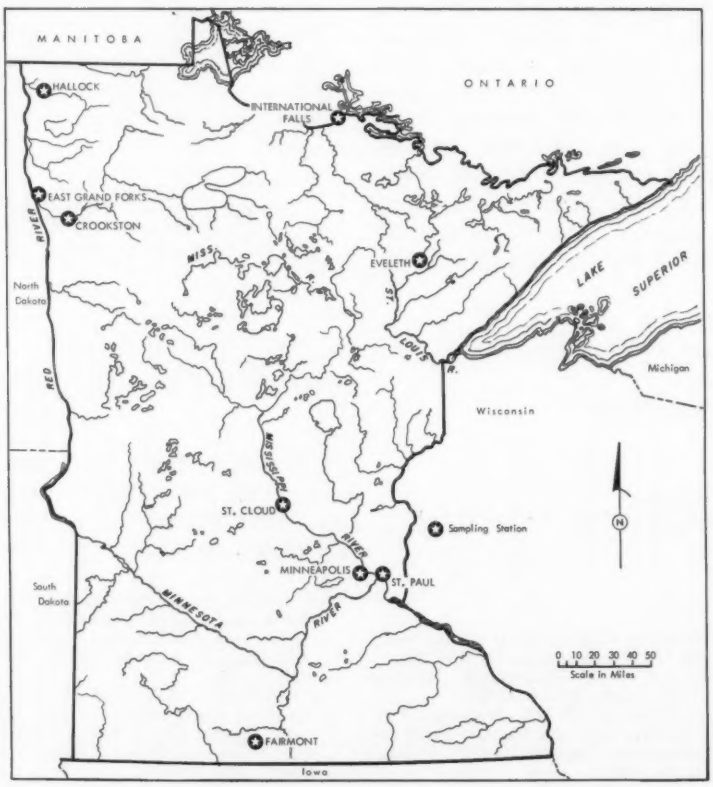

Figure 1. Minnesota surface water sampling locations

Table 1. Average gross beta radioactivity in Minnesota raw and treated water supplies, January-June 1969

Town and water source	Type of water	Average concentrations (pCi/liter) Jan	Feb	Mar	Apr	May	June
Crookston, Red Lake River	Raw	25	24	18	20	16	25
	Treated	22	12	20	18	14	12
East Grand Forks, Red Lake River	Raw	19 (5)	[a] 18 (4)	16 (4)	16 (5)	22 (4)	16 (5)
	Treated	10 (5)	10 (4)	12 (4)	12 (5)	12 (4)	6 (5)
Eveleth, St. Mary's Lake	Raw	12 (5)	11 (3)	11 (4)	12 (4)	13 (4)	10 (4)
	Treated	15 (5)	9 (3)	14 (4)	12 (4)	13 (4)	12 (4)
Fairmont, Budd Lake	Raw	14 (5)	11 (4)	12 (2)	10 (5)	11 (5)	11 (4)
	Treated	7 (5)	5 (4)	5 (2)	6 (5)	9 (5)	6 (4)
Hallock, Two Rivers South Fork	Raw	20 (5)	17 (4)	16 (4)	15 (5)	22 (4)	21 (4)
	Treated	10 (5)	7 (4)	7 (4)	12 (5)	12 (4)	11 (4)
International Falls, Rainy River	Raw	11	7	9	6	9	9
	Treated	6	6	8	3	7	7
Minneapolis tap water	Raw						
	Treated	6 (4)	5 (3)	5 (5)	6 (4)	7 (3)	5 (5)
St. Cloud, Mississippi River	Raw	10	10	10	6	13	15
	Treated	4	8	6	3	8	31
St. Paul, Vadnais Chain of Lakes	Raw	12 (5)	11 (4)	14 (4)	11 (5)	12 (4)	15 (4)
	Treated	7 (5)	8 (4)	8 (4)	10 (5)	8 (4)	5 (4)

[a] Number in parenthesis gives number of samples averaged.
NS, no sample.

Table 2. Average gross alpha radioactivity in Minnesota raw and treated water supplies, January-June 1969

Town and water source	Type of water	Average concentrations (pCi/liter) Jan	Feb	Mar	Apr	May	June
Crookston, Red Lake River	Raw	<1	<1	<1	<1	2	4
	Treated	<1	<1	<1	<1	<1	<1
East Grand Forks, Red Lake River	Raw	1 (5)	<1 (4)	<1 (4)	2 (5)	2 (4)	2 (5)
	Treated	<1 (5)	<1 (4)	<1 (4)	<1 (5)	<1 (4)	<1 (5)
Eveleth, St. Mary's Lake	Raw	<1 (5)	<1 (3)	<1 (4)	<1 (5)	<1 (4)	<1 (4)
	Treated	<1 (5)	<1 (3)	<1 (4)	<1 (5)	<1 (4)	<1 (4)
Fairmont, Budd Lake	Raw	3 (5)	5 (4)	5 (2)	5 (5)	5 (5)	5 (4)
	Treated	<1 (5)	1 (4)	<1 (2)	1 (5)	<1 (5)	<1 (4)
Hallock, Two Rivers South Fork	Raw	1 (5)	1 (4)	4 (4)	1 (5)	1 (4)	2 (4)
	Treated	<1 (5)	<1 (4)	<1 (4)	1 (5)	<1 (4)	<1 (4)
International Falls, Rainy River	Raw	1	<1	<1	<1	<1	1
	Treated	<1	<1	<1	<1	<1	<1
Minneapolis tap water	Raw						
	Treated	<1 (4)	<1 (3)	<1 (5)	<1 (4)	<1 (3)	<1 (5)
St. Cloud, Mississippi River	Raw	<1	<1	<1	<1	<2	<1
	Treated	<1	<1	<1	<1	<1	<1
St. Paul, Vadnais Chain of Lakes	Raw	<1 (5)	2 (4)	<1 (4)	<1 (5)	<1 (4)	2 (4)
	Treated	<1 (5)	<1 (4)	<1 (4)	<1 (5)	<1 (4)	<1 (4)

[a] Number in parenthesis gives number of samples averaged.

amounts of thallium–204 standard to solutions containing the normal range of solids.

Table 1 shows a summary of the monthly average gross beta radioactivity in Minnesota municipal water supplies from January–June 1969. Table 2 shows the gross alpha radioactivity in the same samples for the same period of time. Alpha concentrations reported as <1 pCi/liter were considered as 0.5 pCi/liter for averaging purposes.

The data obtained on gross beta radioactivity in Minnesota surface waters show a variation of concentrations, with no readily apparent trends. Variations in precipitation and flow rates of streams could contribute to this fluctuation Monthly averages of gross beta radioactivity in Minnesota raw surface waters ranged from 3 to 25 pCi/liter, which is well below the Public Health Service Drinking Water Standards (*1*).

REFERENCE

(*1*) PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962. Public Health Service Publication No. 956, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1968	November 1969

XUM

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta-radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports.*

Network	Period	Issue
Fallout in the United States and Other Areas, HASL	January–June 1968	October 1969
Plutonium in Airborne Particulates and Precipitation	April–June 1968	October 1969

XUM

1. Radiation Alert Network September 1969

Bureau of Radiological Health
U.S. Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 73 locations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Bureau of Radiological Health officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Radiological Surveillance Branch, Division of Environmental Radiation, BRH, Rockville, Md. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during September 1969. Time profiles of gross beta radioactivity in air for eight Radiation Alert Network stations are shown in figure 2.

All field estimates reported were within normal limits for the reporting station.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, September 1969

Station location		Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Last profile in RHD&R	Number of samples	Precipitation			
								Total depth (mm)	Field estimation of deposition		
		Air	Maximum	Minimum	Average[a]				Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	19	9	0	3	Dec 69	2	153	2	153	87
Alaska:	Adak	2	1	1	1	Dec 69	(c)				
	Anchorage	1	0	0	0	Aug 69	(c)				
	Attu Island	20	1	0	0	Jan 70	1	7	(c)		
	Fairbanks	17	4	0	2	Sept 69	2	7	2	7	0
	Juneau	20	2	0	1	Oct 69	6	138	6	138	0
	Kodiak	18	0	0	0	Nov 69	(c)				
	Nome	(b)				May 69	(c)				
	Pt. Barrow	30	0	0	0	Apr 69	(c)				
	St. Paul Island	30	1	0	1	June 69	(c)				
Ariz:	Phoenix	19	12	1	5	Oct 69	(c)				
Ark:	Little Rock	8	3	0	2	Aug 69	(c)				
Calif:	Berkeley	20	1	0	0	Nov 69	(c)				
	Los Angeles	19	3	0	1	May 69	(c)				
C.Z:	Ancon	15	1	0	0	Nov 69	(c)				
Colo:	Denver	21	6	1	4	Nov 69	2	19	(d)		
Conn:	Hartford	21	2	0	1	Sept 69	7	102	7	102	2
Del:	Dover	21	4	0	1	July 69	(c)				
D.C:	Washington	22	2	0	1	Apr 69	4	34	4	34	0
Fla:	Jacksonville	21	1	0	0	Aug 69	10	220	6	130	32
	Miami	19	0	0	0	Sept 69	8	129	7	126	0
Ga:	Atlanta	21	2	1	1	June 69	3	61	3	61	45
Guam:	Agana	(b)				July 69	(c)				
Hawaii:	Honolulu	25	1	0	0	Jan 70	(c)				
Idaho:	Boise	21	6	1	2	Jan 70	2	17	2	17	7
Ill:	Springfield	18	4	0	1	Apr 69	(c)				
Ind:	Indianapolis	(b)				June 69	(c)				
Iowa:	Iowa City	18	3	0	1	Nov 69	4	20	4	20	0
Kans:	Topeka	20	5	1	3	Aug 69	7	61	7	61	1
Ky:	Frankfort	(b)				Apr 69	(c)				
La:	New Orleans	18	1	0	0	Apr 69	6	81	(d)		
Maine:	Augusta	21	3	0	1	Oct 69	6	140	6	140	0
Md:	Baltimore	20	3	0	1	Sept 69	6	47	6	47	11
	Rockville	11	1	0	1	Jan 70	(c)				
Mass:	Lawrence	20	4	0	1	Nov 69	6	107	6	107	17
	Winchester	21	4	0	1	Dec 69	5	139	5	139	0
Mich:	Lansing	20	4	0	1	Jan 70	5	32	5	32	3
Minn:	Minneapolis	21	3	0	1	July 69	3	677	3	677	72
Miss:	Jackson	18	2	0	2	Oct 69	2	46	2	46	33
Mo:	Jefferson City	20	4	0	2	June 69	7	159	7	159	0
Mont:	Helena	21	3	1	2	Dec 69	2	21	2	21	0
Nebr:	Lincoln	15	7	2	5	June 69	4	46	3	40	5
Nev:	Las Vegas	10	2	0	1	Sept 69	(c)				
N.H:	Concord	19	2	0	1	Apr 69	(c)				
N.J:	Trenton	20	3	0	1	Oct 69	6	191	6	191	3
N.Mex:	Santa Fe	(b)				Dec 69	(c)				
N.Y:	Albany	10	2	0	1	June 69	7	234	7	234	80
	Buffalo	21	3	0	1	Nov 69	(c)				
	New York City	20	2	0	1	Dec 69	(c)				
N.C:	Gastonia	16	0	0	5	Nov 69	6	74	(d)		
N.Dak:	Bismarck	19	4	1	2	Apr 69	2	10	2	10	0
Ohio:	Cincinnati	(b)				July 69	(c)				
	Columbus	10	4	0	2	Oct 69	2	42	(e)		
	Painesville	21	4	1	2	Sept 69	8	99	8	99	7
Okla:	Oklahoma City	12	4	0	1	Jan 70	5	72	5	72	8
	Ponca City	21	7	0	1	Sept 69	6	115	6	115	0
Ore:	Portland	19	3	0	1	June 69	9	108	8	106	10
Pa:	Harrisburg	16	3	0	1	June 69	(c)				
P.R:	San Juan	(b)				Oct 69	(c)				
R.I:	Providence	16	5	0	2	Jan 70	3	70	3	70	10
S.C:	Columbia	20	3	0	2	Dec 69	7	160	6	90	6
S.Dak:	Pierre	12	8	2	6	Oct 69	(c)				
Tenn:	Nashville	21	4	0	1	Jan 70	4	40	4	40	1
Tex:	Austin	9	10	1	5	July 69	2	59	(d)		
	El Paso	(b)				Apr 69	(c)				
Utah:	Salt Lake City	27	3	1	2	May 69	1	3	1	3	0
Vt:	Barre	20	4	0	3	Aug 69	6	55	6	55	7
Va:	Richmond	20	2	0	1	Aug 69	3	69	3	69	10
Wash:	Seattle	5	0	0	0	Aug 69	11	103	(d)		
	Spokane	1	1	1	1	July 69	(c)				
W.Va:	Charleston	20	2	0	1	Dec 69	6	84	6	84	12
Wisc:	Madison	21	2	0	1	Aug 69	7	31	7	31	4
Wyo:	Cheyenne	21	8	1	4	Sept 69	2	16	2	16	5
Network summary		1,159	12	0	2		6	111	5	96	13

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] No report received. (Air samples received without field estimate data are not considered by the data program.)
[c] No precipitation sample collected.
[d] This station is part of the plutonium in precipitation network. No gross beta measurements are done.
[e] Samples were collected but no field estimates were received.

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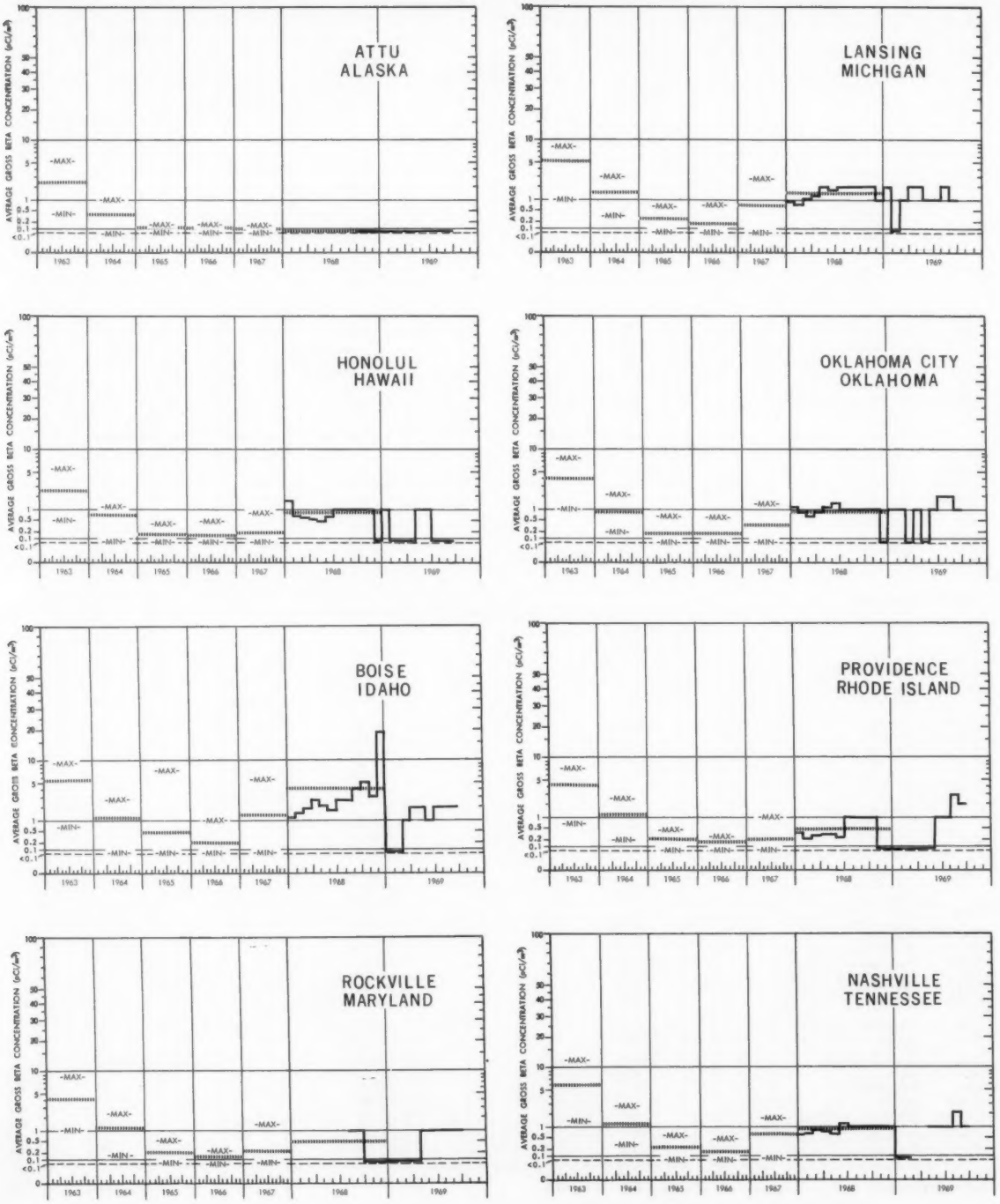

Figure 2. Monthly and yearly profiles of beta radioactivity in air—Radiation Alert Network, 1963–September 1969

2. Canadian Air and Precipitation Monitoring Program,[1] September 1969

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 3), where the sampling equipment is operated by personnel from the Meterological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports.*

Surface air and precipitation data for September 1969 are presented in table 2.

[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, September 1969

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m³)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	28	0.3	0.0	0.1	NS	NS
Coral Harbour	24	.2	.0	.1		
Edmonton	30	.2	.0	.1		
Ft. Churchill	19	.2	.1	.1		
Ft. William	22	.2	.0	.1		
Fredericton	30	.3	.0	.1		
Goose Bay	30	.2	.0	.1		
Halifax	27	.3	.0	.1		
Inuvik	30	.2	.0	.1		
Montreal	30	.5	.0	.2		
Moosonee	29	.3	.0	.1		
Ottawa	30	.3	.0	.2		
Quebec	30	.2	.0	.1		
Regina	30	.3	.0	.1		
Resolute	30	.2	.0	.1		
St. John's, Nfld	30	.3	.0	.1		
Saskatoon	29	.2	.0	.1		
Saulte Ste Marie	29	.4	.0	.1		
Toronto	30	.4	.0	.2		
Vancouver	30	.2	.0	.1		
Whitehorse	30	.2	.0	.1		
Windsor	30	.3	.0	.1		
Winnipeg	30	.3	.0	.1		
Yellowknife	30	.1	.0	.1		
Network summary	687	0.5	0.0	0.1		

NS, no sample.

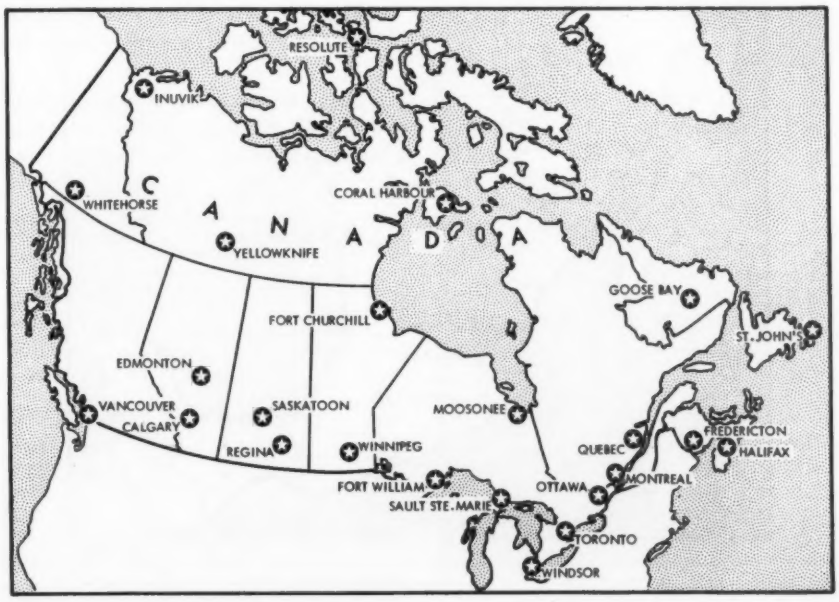

Figure 3. Canadian air and precipatation sampling stations

3. Mexican Air Monitoring Program March and April 1969

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the Division of Radiological Protection was restructured and its name changed to Dirección General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F.; Mérida; Veracruz; San Luis Potosí; and Ensenada. Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Mérida, the Institute de Zonas Desérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air through a high-efficiency 6 by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days a week at the rate of 1,000 cubic meters per day using high volume samplers.

After each 20-hour sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta radioactivity, allowing a minimum of 3 or 4 days after collection for the decay of radon and thoron daughters. The data are not extrapolated to the time of collection. Statistically, it has been found that a minimum of five samples per month were needed to get a reliable average radioactivity at each station (*6*).

The maximum, minimum, and average beta radioactivity in surface air during March and April 1969 are presented in tables 3 and 4.

Figure 4. Mexican air sampling locations

Table 3. Mexican gross beta radioactivity of airborne particulates, March 1969

Station	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Acapulco	24	0.3	0.1	0.2
Chihuahua	18	.4	.2	.3
Ensenada	NS			
La Paz	1	.1	.1	.1
Matamoros	NS			
Mazatlán	13	.6	.2	.3
Mérida	11	.3	.1	.2
México, D.F.	3	.4	.1	.2
Nuevo Laredo	NS			
Tampico	NS			
Torreón	NS			
Veracruz	NS			

NS, no sample, station temporarily shutdown.

Table 4. Mexican gross beta radioactivity of airborne particulates, April 1969

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average
Acapulco	16	0.7	0.1	0.4
Chihuahua	9	.5	.1	.4
Ensenada	NS			
La Paz	NS			
Matamoros	NS			
Mazatlán	17	.6	.5	.5
Mérida	4	.2	.2	.2
México, D. F.	2	.5	.3	.4
Nuevo Laredo	NS			
Tampico	NS			
Torreón	1	.5		
Veracruz	NS			

NS, no sample, station temporarily shutdown.

4. Pan American Air Sampling Program September 1969

Pan American Health Organization and *U.S. Public Health Service*

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs.

The air sampling locations are shown in figure 5. Analytical techniques were described in the January 1968 issue of *Radiological Health Data and Reports*. The September 1969 air monitoring results from the participating countries are given in table 5.

Table 5. Summary of gross beta radioactivity in Pan American surface air, September 1969

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	18	0.25	0.01	0.11
Bolivia:	La Paz	13	.14	.03	.08
Chile:	Santiago	27	.34	.03	.14
Colombia:	Bogota	19	.02	.00	.01
Ecuador:	Cuenca	NS			
	Guayaquil	10	.09	.01	.04
	Quito	16	.01	.00	.01
Guyana:	Georgetown	4	.09	.04	.06
Jamaica:	Kingston	21	.06	.01	.04
Peru:	Lima	NS			
Venezuela:	Caracas	21	.06	.01	.04
West Indies:	Trinidad	21	.09	.01	.04
Pan American summary		170	0.34	0.00	0.06

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

NS, no sample, station temporarily shut down.

Figure 5. Pan American Air Sampling Program stations

REFERENCES

(*1*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*2*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (December 1961).

(*3*) MAR, P. G. Annual report for 1961 on the Radioactive Fallout Study Program, CNHW–RP–5. Department of National Health and Welfare, Ottawa, Canada (December 1962).

(*4*) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD–11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(*5*) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD–21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

(*6*) VÁSQUEZ, M. and R. M. DE NULMAN. Estudios sobre la radioactividad ambiental en la Republica Mexicana, 1963–1965. Comisión Nacional de Energía Nuclear, Dirección General de Seguridad Radiológica (1966).

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual."[1]

Summaries of the environmental radioactivity data follow for the Bettis Atomic Power Laboratory, the Neutron Devices Laboratory and the Oak Ridge National Laboratory.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Bettis Atomic Power Laboratory[2] January–December 1968

Westinghouse Electric Corporation
Pittsburgh, Pa.

The Bettis Atomic Power Laboratory (BAPL), operated for the Atomic Energy Commission by the Westinghouse Electric Corporation, was established in 1949 to conduct research and development operations related to naval atomic propulsion systems and to the central station power reactor at Shippingport, Pa. Routine environmental monitoring data from the sampling locations shown in figure 1 show no significant contribution from laboratory operations to environmental radioactivity levels.

[2] Summarized from "Bettis Atomic Power Laboratory, Environmental Monitoring Report, Calendar Year 1968" (WAPD–O–(IHR)–2024).

Gaseous radioactive waste

The release of gaseous radioactive waste is monitored by continuous air sampling to assure compliance with laboratory regulations. The stack gas limits for the laboratory are based on the 168-hour nonoccupational maximum permissible concentrations in air as specified in AEC Manual Chapter 0524. At no time during 1968 did the concentration of stack releases exceed the required limits. The general public outside the boundary of the laboratory was not exposed to radiation above normal background levels as a result of laboratory operations.

Total gaseous radioactivity released to the environment during 1968 was 1.64 mCi alpha and less than 164 mCi beta-gamma. Due to an increased volume of air discharged, the total radioactivity was greater than last years's quantities; the average concentration of radioactivity, however, remained the same.

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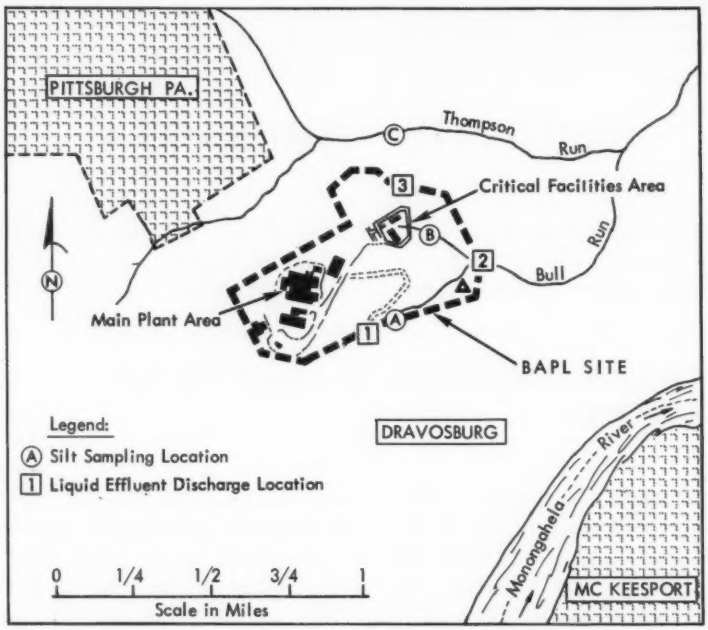

Figure 1. Bettis Atomic Power Laboratory sampling stations

Liquid radioactive waste

Liquid effluent discharged from the laboratory is sampled continuously. Composite samples are analyzed weekly for gross alpha and gross beta-gamma radioactivity, and quarterly for strontium-90 radioactivity.

The average concentrations of gross beta radioactivity in the main laboratory liquid effluent during 1968 was 120 pCi/liter. This was lower than the average concentration of 520 pCi/liter observed for the year 1967.

Average radioactivity in liquid waste effluent from the critical facility operations during 1968 were: alpha radioactivity—610 pCi/liter, beta-gamma radioactivity—1.00 nCi/liter. Comparable values for 1967 were <400 pCi/liter for alpha radioactivity and 1.36 nCi/liter for beta-gamma radioactivity.

Background monitoring stations

Beta-gamma radiation levels were continuously monitored and recorded at 34 film badge monitoring stations located at 100-yard intervals along the boundary of the laboratory property which lies within the controlled confines of the Bettis Atomic Power Laboratory site.

The average beta-gamma radiation level during 1968 was 0.055 mR/h for the main laboratory area and 0.014 mR/h for the critical facility area. The respective average exposure values for 1967 were 0.072 mR/h and 0.009 mR/h. Table 1 summarizes results obtained during 1968 from the background monitoring stations.

Table 1. Beta-gamma background radiation monitoring, Bettis, 1968

Location	Exposure levels (mR/h)	
Main laboratory area (20 locations)	Maximum	0.383
	Average	.055
Critical facility area (14 locations)	Maximum	.016
	Average	.014
All locations	Average	.038

Stream silt

Stream silt samples were collected quarterly at the three locations shown in figure 1. The results of analysis of these samples are presented in table 2. The average alpha and beta-gamma radio-

Table 2. Radioactivity in stream silt, Bettis, 1968

Period 1968	Number of samples	Radioactivity (pCi/g)			
		Alpha		Beta-gamma	
		Range	Average	Range	Average
January–March	3	0.4– 9.4	4.6	0.9– 79.2	46.9
April–June	6	1.0–12.4	6.6	3.0– 92.6	42.5
July–September	9	4.7–12.1	9.2	6.7– 95.1	41.5
October–December	3	11.5–33.3	18.8	13.8–180.2	75.2

Table 3. Strontium-89 and strontium-90 in stream silt Bettis, 1968

Period 1968	Concentration (pCi/g of silt)	
	Strontium-89	Strontium-90
January–March	<0.3	1.04
April–June	< .3	.41
July–September	< .1	.16
October–December	< .3	.38

activity concentrations of stream silt samples for 1968 were 9.8 pCi/g and 51.5 pCi/g, respectively. Although these concentrations represent an increase over those for 1967, they are consistent with concentrations detected in previous years.

Semiannual analyses for strontium-89 and strontium-90 were obtained for composites of quarterly silt samples. Table 3 presents the results of these analyses for samples collected during 1968.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1966	October 1967
January–December 1967	March 1969

2. Neutron Devices Department[3] July–December 1968

General Electric Company
St. Petersburg, Florida

The Neutron Devices Department, shown in figure 2 is an electronic component production facility. The plant maintains an environmental monitoring program to measure the levels of radioactive environmental contamination associated with plant effluents. These measurements serve as an index of the effectiveness of the plants's contamination control measures. Effluent radioactivity concentrations and associated atmospheric and stream dilution factors indicate offsite radioactivity concentrations encountered by the general population are substantially lower than the guides for continuous nonoccupational exposure established by AEC and documented in the "AEC Manual."

Sewer effluent monitoring

A combined sewer effluent sample is obtained daily near the perimeter of the plant's property. During the sampling period, 7 of 362 samples analyzed showed detectable concentrations of tritium (>90 nCi/liter). The maximum concentration (370 nCi/liter), detected on November 12, 1968 represented 12 percent of the continuous nonoccupational exposure guide. Calculations based on radioactivity releases from the process waste system, and the plant's water discharges, indicate that the average tritium concentration in the combined sewer effluent for July–December of 1968 was less than 3.5 percent of the AEC radiation protection standard for continuous nonoccupational exposure.

[3] Summarized from "Environmental Monitoring, July 1 through December 31, 1968" General Electric Company, Neutron Devices Department, St. Petersburg, Fla.

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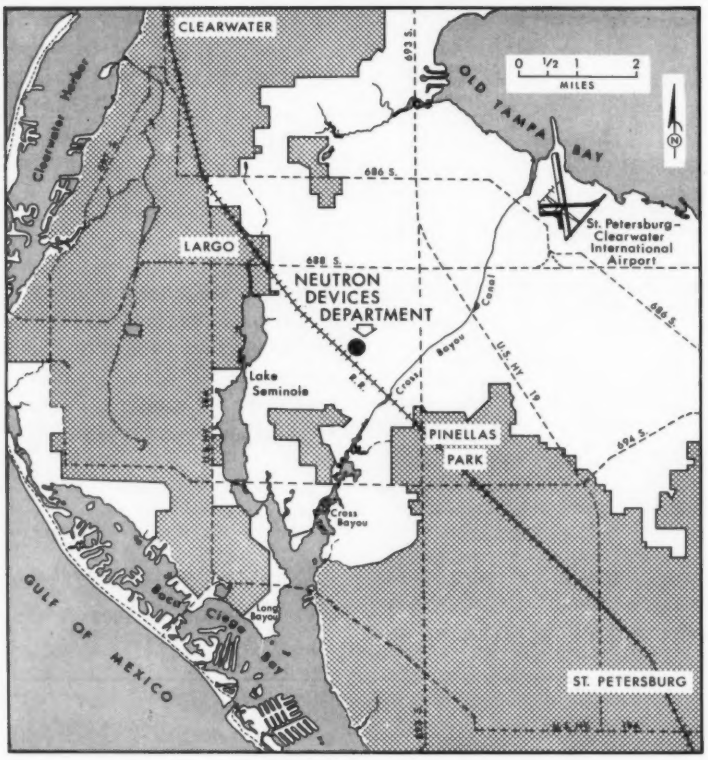

Figure 2. Location of the Neutron Devices Department

Surface water sampling

Surface water samples are collected at monthly intervals at selected locations within 8 miles of the plant. The sampling areas are determined by interrelating the concentrations of radioactivity in exhaust stack effluent with meteorological data. There were no indications of tritium (>90 nCi/liter) in the 43 surface water samples analyzed during the sampling period.

Milk sampling results

Analyses of eight raw milk samples, collected from one local dairy farm by the Pinellas County Health Department, revealed no detectable concentrations (>90 nCi/liter) of tritium.

Air sampling results

No detectable amounts of tritium gas (>20 nCi/m³) or tritium oxide (>5.0 nCi/m³) were found in two samples of air obtained downwind from the exhaust stack at the perimeter of the plant property.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1967	May 1969
January–June 1968	December 1969

3. Oak Ridge Area[4] July–December 1968

Union Carbide Nuclear Company
Oak Ridge, Tenn.

Oak Ridge area is a complex made up primarily of the Y-12 Plant, the Oak Ridge National Laboratory (ORNL), and the Oak Ridge Gaseous Diffusion Plant (ORGDP).

Radioactive waste materials arising from the operation of atomic energy installations in the Oak Ridge area are collected, treated, and disposed of according to their physical states. Solid wastes are buried in a Conasauga shale formation which has a marked ability to fix radioactive materials by an ion exchange mechanism. Liquid wastes which contain long-lived fission products are confined in storage tanks or are concentrated by evaporation and disposed of in deep wells. Low-level liquid wastes are discharged, after preliminary treatment, to the surface streams. Air that may become contaminated by radioactive materials is exhausted to the atmosphere from several tall stacks after treatment by means of filters, scrubbers, and/or precipitators.

[4] Summarized from "Environmental Levels of Radioactivity for the Oak Ridge area, Report Period, July–December 1968. Health Physics and Safety Section, Health Physics Division, Oak Ridge National Laboratory.

Air monitoring

Atmospheric contamination by radioactive materials occurring in the general environment of East Tennessee is monitored by two systems of monitoring stations. One system consists of nine stations which encircle the plant areas (figure 3) and provide data for evaluating the impact of all Oak Ridge operations on the immediate environment. A second system consists of eight stations encircling the Oak Ridge area at distances of from 12 to 75 miles (figure 4). This system provides data to aid in evaluating local conditions and to assist in determining the spread or dispersal of contamination should a major incident occur.

Sampling for radioactive particulates is carried out by passing air continuously through a filter paper. Average radioactivity concentrations are presented in tables 4 and 5. Airborne radioactive iodine is monitored in the immediate environment of the plant areas by passing air through a cartridge containing activated charcoal.

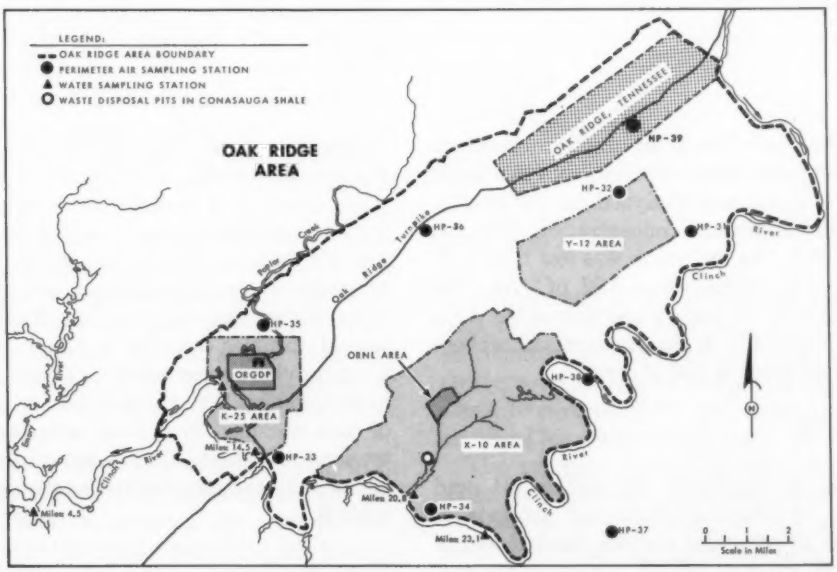

Figure 3. Oak Ridge area environmental sampling locations

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Table 4. Long-lived gross beta radioactivity of particulates in air, Oak Ridge area, July–December 1968

Perimeter stations				Remote stations			
Station number (figure 3)	Number of samples	Average concentration (pCi/m³)	Percent of AEC standard[a]	Station number (figure 4)	Number of samples	Average concentration (pCi/m³)	Percent of AEC standard[a]
HP–31	26	0.11	0.11	HP–51	26	0.09	0.10
HP–32	26	.16	.16	HP–52	25	.11	.11
HP–33	26	.09	.09	HP–53	26	.10	.10
HP–34	26	.10	.10	HP–54	25	.08	.08
HP–35	26	.11	.11	HP–55	25	.09	.10
HP–36	[b] 151	.12	.12	HP–56	26	.11	.11
HP–37	26	.07	.07	HP–57	26	.09	.09
HP–38	26	.11	.11	HP–58	21	.11	.11
HP–39	26	.08	.09				
Average		0.10	0.10	Average		0.10	0.10

[a] The applicable AEC Radiation Protection Standard is 100 pCi/m³.
[b] Sampling frequency changed to 5 days per week beginning 9/20/68.

Table 5. Long-lived gross alpha radioactivity of particulates in air, Oak Ridge area, July–December 1968

Perimeter stations				Remote stations			
Station number (figure 3)	Number of samples	Average concentration (pCi/m³)	Percent of AEC standard[a]	Station number (figure 4)	Number of samples	Average concentration (pCi/m³)	Percent of AEC standard[a]
HP–31	26	0.002	0.10	HP–51	26	0.001	0.05
HP–32	26	.002	.10	HP–52	25	.002	.10
HP–33	26	.002	.10	HP–53	26	.001	.05
HP–34	26	.001	.05	HP–54	25	.001	.05
HP–35	26	.002	.10	HP–55	25	.001	.05
HP–36	[b] 151	.004	.20	HP–56	26	.001	.05
HP–37	26	.002	.10	HP–57	26	.001	.05
HP–38	26	.001	< .01	HP–58	21	.003	.15
HP–39	26	.002	.10				
Average		0.002	0.10	Average		0.001	0.05

[a] The applicable AEC Radiation Protection Standard for natural uranium in air is 2 pCi/m³.
[b] Sampling frequency changed to 5 days per week beginning 9/20/68.

During the July–December 1968 surveillance period, 234 samples were collected from perimeter monitoring stations and analyzed for iodine-131. Of these, the maximum concentration detected was 0.74 pCi/m³, the minimum was less than 0.01 pCi/m³, and the average was 0.02 pCi/m³. The radiation protection standard specified in the AEC Manual for iodine-131 in the ambient atmosphere in uncontrolled areas is 100 pCi/m³.

Milk monitoring

Raw milk is monitored for iodine-131 and strontium-90 by the collection and analysis of samples from 12 sampling stations located within a radius of 50 miles of ORNL. Samples are collected weekly at each of eight stations located on the fringe of the Oak Ridge area. Four stations, located more remotely with respect to the Oak Ridge operations, are sampled at a rate of one station each week. The purpose of the milk sampling program is twofold: first, samples collected in the immediate vicinity of the Oak Ridge area provide data by which one may evaluate possible exposure to the neighboring population resulting from waste releases from Oak Ridge operations; second, samples collected at the more remote stations provide background data which are essential in establishing the proper index for the evaluation of data obtained from local samples. The concentrations of iodine-131 and strontium-90 detected in raw milk samples during the period are given in table 6.

Water monitoring

Large volume, low-level liquid wastes originating at ORNL are discharged, after some pre-

Table 6. Radionuclides in raw milk, Oak Ridge area July–December 1968

Radionuclide and location	Concentration (pCi/liter)		
	Maximum	Minimum[a]	Average
Iodine–131			
Immediate environs	15	<10	5.1
Remote environs	<10	<10	5.0
Strontium–90			
Immediate environs	38	9.0	19
Remote environs	23	12	17

[a] The minimum detectable concentrations of iodine–131 and strontium–90 in milk are 10 pCi/liter and 2 pCi/liter, respectively. In averaging, one-half of the minimum detectable concentration was used for all samples showing an activity less than this concentration.

liminary treatment, into the Tennessee River system by way of White Oak Creek and the Clinch River. Liquid wastes originating at the ORGDP and Y-12 Plant are discharged to Poplar Creek and thence to the Clinch River. Releases are controlled so that resulting average concentrations in the Clinch River comply with AEC radiation protection standards. The radioactivity concentration from White Oak Creek is measured, and concentration values for the Clinch River are calculated on the basis of the dilution provided by the river.

Water samples are taken at a number of locations in the Clinch River, beginning at a point above the entry of wastes into the river and ending at Center's Ferry near Kingston, Tenn. Stream gauging operations are carried on continuously to obtain dilution factors for calculating the probable concentrations of wastes in the river.

Samples are analyzed for the long-lived beta-particle emitters, uranium, and the transuranic alpha-particle emitters.

Analyses are made of the effluent for the long-lived radionuclides only, since cooling time and hold up time in the waste effluent system are such that short-lived radionuclides are normally not present. The average concentrations of major radionuclides in the Clinch River are given in table 7 for the period from July through December 1968.

Two quarterly composite water samples from the Clinch River were analyzed for uranium during this period. For these samples, the uranium concentrations were less than 1 pCi/liter, the level of detectability. The AEC radiation protection standard for natural uranium in water released to unrestricted areas is 20 nCi/liter.

Table 7. Concentrations of major radionuclides in the Clinch River, July–December 1968

Radionuclide	Average concentration (pCi/liter)		
	Location on Clinch River[a]		
	Mile: 23.1 (Upstream)	Mile: 20.8[b] (Outfall)	Mile: 4.5 (Downstream)
Strontium–90	0.4	0.5	0.9
Cerium–144	.2	<.1	.3
Cesium–137	ND	.1	1.4
Ruthenium–106	.4	.4	.5
Cobalt–60	8.8	<.1	4.4
Zirconium niobium–95	ND	<.1	.1
Gross beta	9.8	3.3	7.6

[a] The location on Clinch River is given in terms of the distance upstream from the Tennessee River. See figure 3.
[b] The concentrations at mile: 20.8 are not measured directly but the values are calculated based on the levels of waste released and the dilution provided by the river.
ND, nondetectable.

Gamma measurements

External gamma radiation levels are measured monthly at a number of locations in the Oak Ridge area. Measurements are taken with a Geiger-Mueller tube at a distance of 3 feet above the ground. The results are shown in table 8.

Table 8. External gamma radiation levels, Oak Ridge area, July–December 1968

Location	Average dose rates[a] (mR/h)
Solway Gate	0.012
Y-12, East Portal	.012
Newcomb Road	.012
Gallaher Gate	.011
White Wing Gate	.011

[a] The background in the Oak Ridge area, determined in 1943, was approximately 0.012 mR/h.

Discussion of data

The average air contamination level for gross beta radioactivity, as shown by the continuous air monitoring filter data, for both the immediate and remote environs of the plants (figures 3 and 4) was 0.10 percent of the AEC radiation protection standard for uncontrolled areas.

The average air contamination levels for gross alpha radioactivity, as shown by the continuous air monitoring filter data, for the immediate and remote environs of the plants were 0.10 percent and 0.05 percent, respectively, of the AEC radiation protection standard for natural uranium for application to uncontrolled areas.

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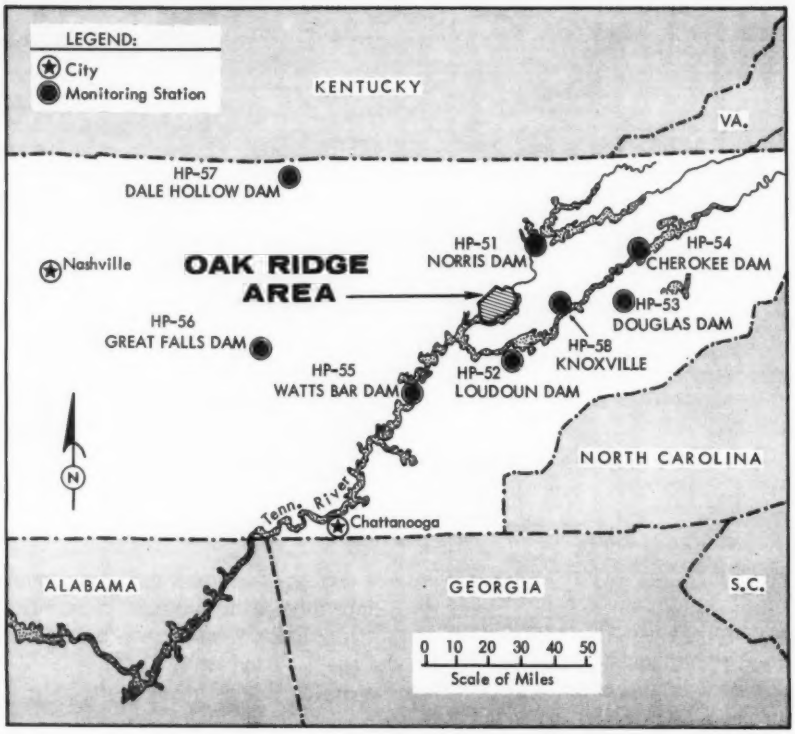

Figure 4. Remote air monitoring stations, Oak Ridge area

The average concentration of iodine-131 in air in the immediate environs of the plants was 0.02 pCi/m³. This is approximately 0.02 percent of the AEC radiation standard for uncontrolled areas.

The average concentrations of iodine-131 in raw milk in the immediate and remote environs of the Oak Ridge area were 5.1 pCi/liter and 5.0 pCi/liter, respectively. These levels fall within the limits of FRC Range I if the average intake per individual is assumed to be 1 liter of milk per day.

The average concentrations of strontium-90 in raw milk in the immediate and remote environs of the controlled area were 19 pCi/liter and 17 pCi/liter, respectively.

These levels fall within the limits of FRC Range I for transient rates of daily intake of strontium-90 for application to the average of suitable samples of an exposed population.

The calculated average concentration of gross beta radioactivity in the Clinch River at mile 20.8 (the point of entry of most of the wastes) and the measured average concentration at mile 4.5 (near Kingston, Tenn.) were 3.3 pCi/liter and 7.6 pCi/liter, respectively. These values are 0.31 percent and 0.34 percent of the weighted average AEC radiation protection standards. The higher than normal average concentration reported for radioactivity mat ile 23.1, Melton Hill Dam, was due primarily to cobalt-60. This contamination was found in the river upstream from the ORNL waste outfall and was the result of a source of contamination from a nuclear company upstream

from Oak Ridge Operations. The average concentration of transuranic alpha-particle emitters in the Clinch River at mile 20.8 was 0.001 pCi/liter which is less than 0.01 percent of the weighted average AEC radiation protection standard.

The average concentration of natural uranium materials in the Clinch River, reflecting the effects of all Oak Ridge plants, was less than 0.01 percent of the AEC radiation protection standard for natural uranium.

The average external gamma radiation measured in the town of Oak Ridge and at the perimeter of the Oak Ridge area was 0.012 mR/h, which is approximately the same as that level measured during the period prior to Oak Ridge operations.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1967	October 1968
January–June 1968	June 1969

Reported Nuclear Detonations, October 1969

(includes seismic signals from foreign test areas)

The U.S. Atomic Energy Commission announced that a nuclear test of low yield (less than 20 kilotons TNT equivalent) was conducted underground by the Atomic Energy Commission at its Nevada Test Site on December 5, 1969.

On December 6, 1969, the United States recorded seismic signals which originated in the Kazakh Desert, south of the Urals, in the U.S.S.R. The signals were equivalent to those of a nuclear test in the low-intermediate yield range (20–200 kilotons TNT equivalent).

Two nuclear tests, one of low yield (less than 20 kilotons TNT equivalent) and the other of low-intermediate yield rnge (20–200 kilotons TNT equivalent) were conducted underground on December 17, 1969, by the Atomic Energy Commission at its Nevada Test Site.

Another underground nuclear test of low-intermediate yield was conducted December 18, 1969, by the Atomic Energy Commission at its Nevada Test Site.

The United States recorded seismic signals on December 29, 1969, which originated from the Soviet nuclear test area in the Semipalatinsk region. The signals were equivalent to those of a nuclear test in the low-intermediate yield range (20–200 kilotons TNT equivalent).

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SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

DIAGNOSTIC DENTAL X RAYS AND THE PATIENT—AN OVERVIEW. *Bureau of Radiological Health. Radiological Health Data and Reports, Vol.* 11, *January 1970,* pp. 1–5.

In 1964, approximately one quarter of the civilian non-institutional population in the United States was exposed to dental x rays. The average estimated skin exposure was 1,144 mR per film. The absorbed doses were on the order of 25–80 mrad to organs in or near the direct beam with a genetically significant dose of <0.01 mrad per year. The status of exposure control programs and standards and compliance is discussed and activities for further reducing exposure are identified.

KEYWORDS: Absorbed doses, dental x ray, genetically significant dose, human organs, United States.

EVALUATION OF EMISSIONS FROM RADIUM DIAL WATCHES. *Herbert F. Klein, Earl W. Robinson, Royce L. Gragg, and James W. Rolofson. Radiological Health Data and Reports, Vol.* 11, *January 1970,* pp. 7–9.

Seventeen U.S. Army surplus radium-dial pocket watches were examined for radium content. The absorbed dose rates at the surface of the watches were measured and found to vary from 23.8 to 36.1 mrad/h–μCi. A simulated radium dial watch was constructed and used to estimate absorbed dose rates to various parts of the human body.

KEYWORDS: Absorbed dose rates, human organs, pocket watches, radium.

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